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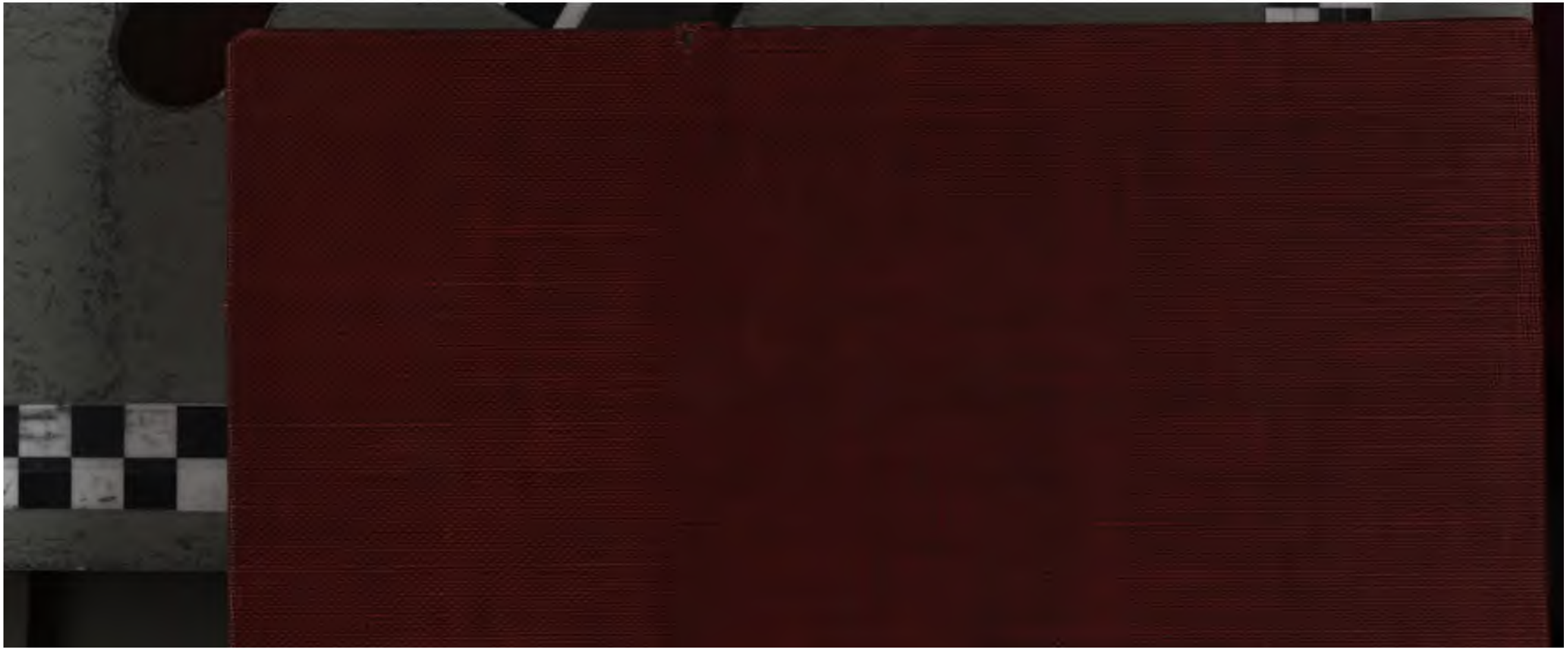

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QUARTERLY JOURNAL

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THE INTERNATIONAL BALLOON ASCENTS, JULY 22–27, 1907.

Reports by W. H. DINES, F.R.S., J. E. PETAVEL, F.R.S., W. A. HARWOOD, and Prof. W. E. THRIFT, M.A.

[Read November 20, 1907.]

I.—THE REGISTERING BALLOON ASCENTS IN ENGLAND OF JULY 22-27, 1907, PRELIMINARY ACCOUNT.

BY W. H. DINES, F.R.S.

THE International Aeronautical Commission has for many years past set apart the first Thursday in each month for the ascent of kites and balloons; but at the Conference held at Milan last year, it was decided to make a special effort to obtain information on a series of consecutive days, and the last week in July was finally decided upon for the purpose.

It is not worth while to attempt a full discussion of the results before the Continental figures are published, but since twenty-five balloons were sent up in England and Scotland during the week, and fourteen of these have been found, it may be of interest to give a brief statement about the method adopted and the results obtained.

The Meteorological Office, the Joint Kite Committee, the Manchester University, and Mr. Cave participated in the work. The Meteorological Office were responsible for nine balloons, namely five from Crinan on the west coast of Scotland, and four from their station at Pyrton Hill, Oxon. Mr. Petavel, aided by a grant from the Kite Committee, dispatched six balloons from Manchester; Capt. Ley, acting for the Committee, three from Sellack, near Ross, Herefordshire; and Mr. Cave six from Ditcham Park, Petersfield. Up to the present time, of these, three from Crinan, four from Manchester, one from Ross, two from Pyrton Hill, and four from Ditcham Park, have been found.

With one exception the instruments used were all made at Pyrton Hill, but since there was very little previous experience of this sort of work in England it was left to each observer to choose his own kind and size of balloon; and very largely to dispatch it at the time and in the manner that he deemed best.

The instruments that were used are described in *Symons's Meteorological Magazine* for July 1906. Briefly it may be said that they leave a record scratched by two hard steel points on a small piece of sheet metal electro-plated with copper. The scale is very small, but the traces are read under a low power microscope. The marks consist of two lines roughly parallel; at least they would be parallel were there no change of temperature. In the usual form of trace these lines are about $\frac{1}{2}$ in. (12 mm.) long, and start about $\frac{1}{30}$ in. apart, diverging to perhaps $\frac{1}{10}$ in. at the top. The distance between the lines gives the temperature. Under a microscope it is easy to read this distance to about ·001 in., or ·025 mm., and this distance corresponds to about 1° C. Two independent observers taking the same trace and calibrating the instrument independently are not likely to differ in their readings by more than one or two degrees of temperature. The record of height is more uncertain. The atmospheric pressure recorded can be obtained with fair accuracy, but heights where the pressure amounts to only a few inches of mercury (under 150 mm.) are frequently reached, and at such heights a small error in the pressure means a large error in the height.

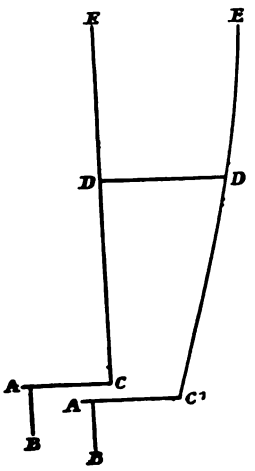

FIG. 1.

Fig. 1 shows the form of a good trace magnified four times. The instruments are roughly calibrated a few days before they are sent up. In general a spring holds the points off the copper, but an hour or so before starting, a wedge is inserted which presses down the spring and brings the steel points on the copper at the points A, A. The instrument is then lowered gently into water to a definite depth, and the increased pressure due to the water makes the two marks AB, AB. I am indebted to Mr. W. A. Harwood for his useful suggestion. The temperature of the water is recorded, and this temperature compared with the distance between the lines AB, AB gives the zero line of the temperature scale. The instrument is allowed to dry and then the copper is drawn along a short distance by hand, making the marks AC, AC′. These lines form the base lines of the pressure scale. The instrument is then sent up, and as the temperature falls the points separate and produce the trace as shown. The temperature is given by the length DD and the height by the distance from C′ to DD.

The figure shows an ideal trace, but however careful the observer may be after he has inserted the wedge he is certain to get a few scratches about the points C, C′. These do not matter. The wedge has a piece of red string tied to it, and on the label offering the reward, the finder is requested to pull out the wedge. He generally does so, but, if not, the shaking of the journey back produces two blurrs at C and C′. Still if the marks AB, AB are distinct the only result is that the trace is lost for about the first 1000 feet. If the marks AB, AB, cannot be found, one has to make the best guess one can at the centre of the blurrs, and use them as the starting-points.

In general the lines EC and EC′ are sharp and distinct, and if the

balloon is sent up after or near sunset the up and down traces are generally almost identical, but the up trace is mostly distinguishable from the down. Occasionally thick blurred lines occur, notably so when two balloons arranged tandem are employed, but there is no difficulty about reading even in this case. The chief use of the lines AB, AB, the "water marks" as we call them, is to make sure that the standard temperature line has not been altered by the shaking of the instrument in transit to the place of ascent.

All the traces so far recovered have been readable, excepting part of one of Mr. Cave's, which was picked up in the Channel, off Bognor. One of the balloons from Crinan also fell into the sea, but the trace was quite legible. It might perhaps be worth while to electroplate with gold instead of copper. Probably owing to their lightness the meteorographs never seem to be injured by their fall. Each one, as soon as it is returned to Manchester or Pyrton Hill, is carefully calibrated, and I take this opportunity of expressing my indebtedness to Mr. W. A. Harwood, who, before the necessary apparatus was obtained at Pyrton Hill, calibrated many instruments for me at the physical laboratory at Manchester University.

Perhaps the most important matter about all balloon ascents is the question of solar radiation. The thermograph of these particular instruments depends on the contraction of a strip of very thin polished metal. It is therefore sensitive and not susceptible to radiation. It is further protected by a cylindrical case polished inside and out. At the earth's surface it is easy to see that it is but little influenced by solar radiation. On the other hand it is certain that when the balloon has been sent up in the middle of the day in the summer, and has not burst, the temperature near the top is influenced by the sun. Thus 32° F. has been recorded when – 40° F. might be expected, both on the Continent and in England. Quite apart from direct radiation on the meteorograph, it is easy to see that its ascent may be made in a column of air that has been warmed by contact with the balloon. There is a complete relative calm and most intense solar insolation, and a slowly ascending balloon may well be surrounded by a mass of air warmed by contact with the balloon. It is usual on the Continent to avoid the difficulty by rejecting all observations when the ventilation is insufficient, that is to say, when the product, density of air, and vertical velocity fall below a certain standard. As our instruments carry no clock, we do not know the vertical velocity and cannot adopt this plan.

I prefer to send up the balloons a little before sunset, so that by the time they reach their highest point the sun may be near or below their horizon. By this means all doubt concerning the temperature is avoided. The vertical velocity of the balloon is immaterial or nearly so. If the balloons float at the same height there is ample time for the metal strip to take the temperature of its surroundings; if the motion is rapid there is a stream of air passing over it to render it sensitive. Since the change of temperature of the strip depends on the mass of air which has been in contact with it, and this mass varies as the velocity multiplied by the time, remembering that velocity is space divided by time, we see that the velocity cancels out. The objection to this plan is that the balloon is not seen to fall and hence there is less chance of finding it, and the time

of flight is also unknown. It is, however, an exception for anyone to see the balloon fall, even when it falls during the daylight.

The results obtained are summarised in Table I. They will subsequently be published in detail by the International Aeronautical Commission, and until then it is hardly worth while to do more than give a rough statement of the results.

TABLE I.—Temperatures at Various Heights.

	July 23.	July 24.	July 25.	July 26.	July 27.	Mean.
Ground Level.	°	°	°	°	°	°
Crinan	...	57	60	59	...	59
Manchester	59	57	57	59	...	58
Sellack	65	...	...	...	...	65
Pyrton Hill	...	60	59	...	...	59
Ditcham Park	...	64	63	...	59	62
10,000 Feet.						
Crinan	...	32	27	34	...	31
Manchester	35	30	41	37	...	36
Sellack	29	...	...	...	...	29
Pyrton Hill	...	19	33	...	...	26
Ditcham Park	...	30	39	...	27	32
20,000 Feet.						
Crinan	...	3	8	1	...	4
Manchester	1	−7	6	10	...	2
Sellack	−5	...	...	...	...	−5
Pyrton Hill	...	−3	2	...	...	0
Ditcham Park	...	5	12	...	−4	4
30,000 Feet.						
Crinan	...	−27	...	−24	...	−25
Manchester	−33	−47	−30	−20	...	−33
Sellack	−35	...	...	...	...	−35
Pyrton Hill	...	...	−30	...	...	−30
Ditcham Park	...	−18	...	...	−31	−24
40,000 Feet.						
Crinan	...	−40	...	−24	...	−32
Manchester	−52	−52	−38	..	...	−47
Sellack	−54	...	...	...	...	−54
Pyrton Hill	...	...	−51	...	...	−51
Ditcham Park	...	−24	...	...	...	−24
50,000 Feet.						
Crinan	...	−39				
Manchester	−50	−50	−37			
Sellack	−46					
Pyrton Hill						
Ditcham Park	...	−20				

Crinan	Lat.	56·6′ N.	Long.	5·33′ W.
Manchester	,,	53·29 N.	,,	2·14 W.
Sellack	,,	51·58 N.	,,	2·35 W.
Pyrton Hill	,,	51·38 N.	,,	1·0 W.
Ditcham Park	,,	50·57 N.	,,	0·47 W.

As I have previously stated, I do not think too much importance must be attached to the precise height to which a given temperature is assigned in each ascent. The instruments are troublesome and difficult to calibrate without specially designed apparatus, and this apparatus is not yet completed. The sequence of temperature is certainly correct, and I have no doubt about the substantial accuracy of the values. Cases in which there is reason to assume the influence of solar radiation are omitted.

It has been known for some time that after a certain height is reached, the air temperature ceases to fall. This layer is of variable height, and is known as the region of the "great inversion." Some competent meteorologists have expressed doubt about this inversion, being inclined to ascribe it to instrumental errors. Above this comes the isothermal region, where the temperature remains almost unaltered with change of height.

The 34 successful ascents that have been made in England since June last, have in my opinion proved conclusively the existence of the isothermal conditions above some 7½ miles (12,000 metres), although I did not previously doubt its reality. All the high ascents in the daytime or after sunset show this nearly uniform temperature. I think a large inversion may be open to question, certainly it is far more prominent in ascents made in the morning than in those made at sunset.

Nearly all the balloons sent up have drifted to the Eastward, but several that have reached a fair height have fallen within 20 miles or less of their starting-point. It is only in a few instances that the time of flight is known. The heights range to over 12½ miles (20 kilometres), the average being about 7½ miles (12 kilometres), so that bearing in mind the small size of our balloons, and our lack of previous experience, we may, I think, consider the results obtained fairly satisfactory.

II.—RESULTS OF THE BALLOON ASCENTS MADE FROM MANCHESTER, JULY 22-28, 1907.

By J. E. PETAVEL, F.R.S., and W. A. HARWOOD.

For the purposes of this investigation both kites and balloons were used.

1. Observations by Means of Kites.

Kites were sent up, as far as possible daily, from the Glossop Moor Station, between July 16 and 28.

Full information with regard to the results obtained will be found in Tables I. and II.

The weather conditions required for successful work with balloons and with kites are more or less antagonistic. During the International week the weather was not very favourable for kite ascents, the wind on most days being far too light. Nevertheless the kite records give valuable supplementary information, and confirm the results obtained by

TABLE I.—Kite Observations at Glossop Moor.

Date.		Heights above Mean Sea-Level.							Remarks.
		Ground.	1640 feet.	3280 feet.	4920 feet.	6560 feet.	8200 feet.	10,000 feet.	
July 15, 6.49 p.m. to 8.55 p.m.	Temperature	60°	57°	...	...	...	...	...	One kite, 77 sq. ft. Max. ht. 2325 ft. Min. temp. 53°. Overcast.
	Humidity	89 %	86 %	...	...	...	...	...	
	Wind Dir. and Vel., m. per hr.	E by N	E 34	...	...	...	...	...	
July 16, 10.25 a.m. to 1.20 p.m.	Temperature	68°	65°	58°	59°	...	...	...	One kite. Min. temp. 55° at 4200 ft.
	Humidity	75 %	80 %	90 %	72 %	...	...	...	
	Wind Dir. and Vel., m. per hr.	ENE	E 34	E 38	E 37	...	...	...	
July 16, 4.17 p.m. to 5.38 p.m.	Temperature	71°	66°	59°	...	...	...	...	One kite.
	Humidity	72 %	72 %	85 %	...	...	...	...	
	Wind Dir. and Vel., m. per hr.	E by N	ENE 20?	[E by N 20]?	...	...	...	...	
July 16, 6.44 p.m. to 9.55 p.m.	Temperature	64°	61°	57°	53°	...	...	...	One kite. Cloudless sky.
	Humidity	80 %	85 %	90 %	60 %	...	...	...	
	Wind Dir. and Vel., m. per hr.	NE by E	NE by E	NE by E	NE by E	...	...	...	
July 17, 11.9 a.m. to 1.21 p.m.	Temperature	70°	68°	62°	56°	...	...	...	One kite. Blue sky.
	Humidity	65 %	60 %	70 %	80 %	...	...	...	
	Wind Dir. and Vel., m. per hr.	NE by N	NE 22	NE 24	NE 24	...	...	...	
July 17, 7.15 p.m. to 10 p.m.	Temperature	64°	64°	61°	57°	53°	...	...	Two kites, 154 sq. ft. Max. wire 9000 ft. Max. ht. 7160 ft. Min. temp. 52°. Cloudless sky. Wind vel. record unsatisfactory.
	Humidity	70 %	60 %	20 %	6 %	3 %	...	...	
	Wind Dir. and Vel., m. per hr.	ENE	NNE	NNE	NE by N	NE by N	...	...	
July 18, 4.24 p.m. to 6 p.m.	Temperature	70°	66°	...	...	...	...	...	One kite. Blue sky. Light, variable breeze.
	Humidity	53 %	50 %	...	...	...	...	...	
	Wind Dir. and Vel., m. per hr.	E by S	ESE 21	...	...	...	...	...	

July 20, 3.52 p.m. to 5.38 p.m.	Temperature	65°	59°	...	...	...	...	...	One kite. Overcast. Light, variable breeze. *N.B.*—Balloon sent up from Manchester at 11 a.m. showed 10 m. per hour SSW breeze up to 2000 ft., and nearly calm above that level.
	Humidity	80 %	90 %	...	..	..	..	...	
	Wind Dir. and Vel., m. per hr.	E by S	ESE 21	...	..	..	...	...	
July 22, 12 noon to 4 p.m.	Temperature	53°	51°	...	...	...	...	...	Two kites. Light, variable breeze. Apparently calm above 1660 ft.
	Humidity	93 %	93 %	...	...	...	...	...	
	Wind Dir. and Vel., m. per hr.	E by S	E by S 24	...	...	...	...	...	
July 23, 7.30 p.m. to 9 p.m.	Temperature	55°	55°	...	...	...	...	...	One kite. Light, very variable breeze. 8.30 a.m. E by S; 9 a.m. N; 9.55 a.m. S. Upper clouds moving slowly in SSW direction.
	Humidity	80 %	75 %	...	...	...	...	...	
	Wind Dir. and Vel., m. per hr.	E by S	E by S 24	...	...	...	...	...	
July 24, 3.58 p.m. to 4.35 p.m.	Temperature	61°	59°	[53°]	...	...	...	...	One kite. Calm up to 3 p.m. Light breeze later.
	Humidity	70 %	75 %	[80 %]	...	...	...	...	
	Wind Dir. and Vel., m. per hr.	SE	ESE 20	[ESE 24]	..	...	...	...	
July 24, 8 p.m. to 8.30 p.m.	Temperature	52°	54°	...	...	...	...	...	Two kites. Wire 4000 ft. Apparently calm above 1700 ft.
	Humidity	90 %	80 %	...	...	...	...	...	
	Wind Dir. and Vel., m. per hr.	SE by E	ESE 20	...	...	...	...	...	
July 26, 2.18 p.m. to 5.45 p.m.	Temperature	62°	58°	52°	49°	...	...	...	Two kites. Wire 8700 ft. Max. ht. 5710 ft. Min. temp. 48°. Temp. Grad. zero at 4000 ft.
	Humidity	90 %	95 %	100 %	95 %	...	...	...	
	Wind Dir. and Vel., m. per hr.	SW by S	SW by S 23	SW 29	SW by W 30	...	...	...	
July 27, 9.33 a.m. to 4.13 p.m.	Temperature	58°	54°	46°	43°	35°	39°	[46°]	Three kites, 231 sq. ft. Wire 18,800 ft. At 9000 ft. temp. inversion of 11° and humidity zero. All the pens stopped marking until kite had fallen to 8000 ft., when the humidity rapidly rose to 100%. Max. height unknown; probably 10,000 ft.
	Humidity	90 %	95 %	100 %	95 %	95 %	13 %	[0]	
	Wind Dir. and Vel., m. per hr.	W by N	W by N 26	W by N 28	W by N 31	W by N 33	W by N 38	[W by N 39]	
July 27, 5.55 p.m. to 6.10 p.m.	Temperature	63°	58°	...	...	...	...	...	One kite.
	Humidity	71 %	78 %	...	...	...	...	...	
	Wind Dir. and Vel., m. per hr.	W by N	W by N 26	...	...	...	...	...	

the balloons. Towards the end of the week the wind increased and on the 26th the kite and balloon ascents were both successful. The temperature gradients deduced from these simultaneous records are in good agreement.

On the 27th the wind freshened again. A height of about 10,000 ft. was reached by the kites, but the balloon sent up that day was not recovered and had doubtless drifted out to sea.

2. Balloon Ascents.

Balloons carrying recording instruments were sent up each morning at 11 a.m. between July 22 and 28. The balloons were observed from three trigonometrical stations under the charge of Messrs. W. C. Jenkins, W. Wilson, and W. A. Harwood respectively. A general summary of these observations will be found in Table II.

Indiarubber balloons of the nominal size 2 ft. (600 mm.) diameter were used. These were filled to about 39 ins. (1 metre) diameter. The instruments employed were the 1 oz. Dines meteorographs as described in *Symons's Meteorological Magazine*, vol. 41, p. 102.

The instruments, together with instructions to the finder, were attached to a small silk parachute (11 ins. square) suspended some 6 ft. below the balloon.

In a normal ascent the apparatus should reach the ground some two or three hours after the start. The balloons are filled to give a lifting power considerably in excess of the weight carried, and should rise rapidly until they expand to their maximum capacity and burst.

The size of the parachute is adjusted so that the rate of fall may be as rapid as is consistent with the safety of the instrument. If the ascent be prolonged owing either to insufficient initial lifting power, or to a slight leak of the hydrogen, there is a high probability of the balloon drifting out to sea; further, the vertical motion being in this case slow, the ventilation of the instrument suffers and the record is unreliable.

During the International week a balloon was filled each morning at 10.30, and carefully inspected with a view to detecting and closing the small holes which are apt to develop in the thin rubber. It was carried to the observatory roof and the instrument was attached, the spare lifting power being at the same time determined.

A signal was then sent to the two distant trigonometrical stations, and the balloon was liberated. Trigonometrical observations were made every ten seconds. Owing to the hazy weather the balloons were usually lost to view in a very short time, and the trigonometrical observations were therefore not very satisfactory.

Discussion of Results Obtained.—We now come to the consideration of the five records which have been recovered. In those of July 23, 24, and 25, the upward and downward traces coincide. In the record of July 26, there exists a divergence averaging two or three degrees.

Whereas the first three balloons rose rapidly to a very considerable height and burst, that of the 26th seems to have developed a slight leak, and it was the gradual escape of gas which finally brought it to the ground. The slow vertical motion and consequent bad ventilation sufficiently account for the divergence of the two traces. None the less,

TABLE II.—Balloon Ascents.

Date.	No.	Time.	Lift.	Average Vertical Velocity.	Barometer.	Temperature °F.	Direction and Velocity of Wind.			Remarks.
							Ground.	1640 ft.	3280 ft.	
					ins.	°				
July 22 .	12	11 a.m.	about 5 oz.	...	29·94	57	S83°E 12	...	...	No observations from two of stations on account of mist. Instrument not returned.
,, 23[1] .	14	,,	...	590 ft. per min.	29·91	60	S20°E 4	...	...	Fell S by E 11 miles, near Macclesfield. Height, 13·3 miles. Minimum temperature, −54°·4 at 8·7 miles.
,, 24[1] .	15	,,	9 oz.	578 ft. per min.	29·94	59	S25°E 6	S82°E 5	S72°E 4	Fell N84°E 20 miles. Maximum height, 13 miles. Minimum temperature, −59°·8 at 6·7 miles.
,, 25[1] .	16	,,	11 oz.	688 ft. per min.	29·93	55	S50°E 10	S24°E 7	S80°E 3	Fell near Leeds, 35 miles NE by E at 1·15 p.m. Average horizontal velocity, 16 miles per hour. Maximum height, 13·3 miles. Minimum temperature, −39°·1 at 6·8 miles.
,, 26[1] .	13	,,	12 oz.	812 ft. per min.	29·89	66	S14°E 3	S19°W 9	...	Fell 70 miles E by S, near Lincoln. Average horizontal velocity about 28 miles per hour. Maximum height, 6·7 miles. Minimum temperature, −31·9 at 6·7 miles.
,, 27 .	14	,,	...	...	29·85	64	N86°W 12	N78°W 22	...	Instrument not returned.
,, 28[1] .	21	,,	7 oz.	590 ft. per min.	29·94	64	S 11	S8°W 11	S13°E 10	Fell near Huddersfield. Followed to height of 8400 ft. Wind—6500 ft., S60°W 14; 8000 ft., S66°W 20.

[1] These instruments have been returned.

as mentioned above, the temperature gradient agrees well with that obtained from a simultaneous kite ascent and the error cannot therefore be very large.

A few experiments were made with a view to estimating the probable

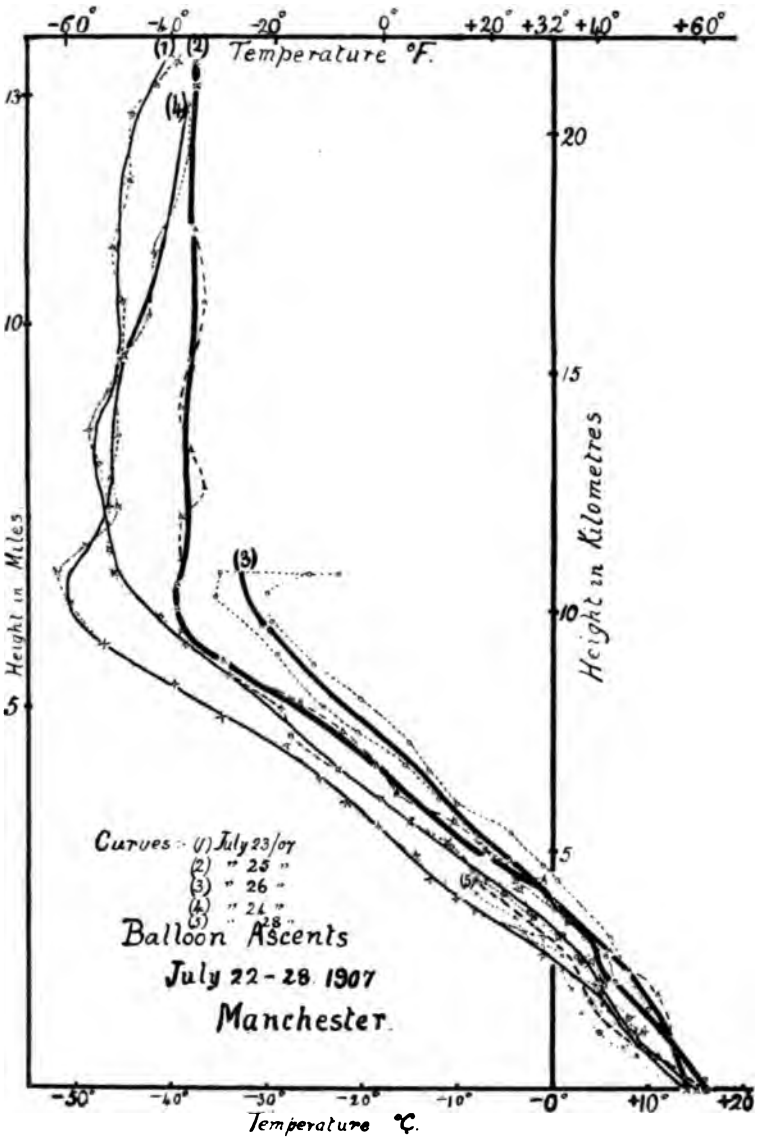

FIG. 2.

error introduced by unsatisfactory ventilation. Two instruments were compared. The one was exposed to the full sunshine and screened from the wind, the other was protected from all radiation. The mean difference between the temperatures indicated was about 5°·5.

Now under the actual conditions of the ascent the total radiation incident on the surface of the case when the balloon is at its maximum height is much greater than under the circumstances described; but on the other hand the balloon is never quite at rest, and the instrument is in consequence always ventilated to some extent.

Continental observers have pointed out that in some instances solar radiation produced an error in the temperature of as much as 50° when the instrument was badly ventilated. From what has been said above it seems extremely unlikely that an error of such magnitude could occur in the case of the Dines meteorograph. The shape of this instrument—an open-ended cylinder—is exceptionally favourable to good ventilation, and the polished aluminium exterior reduces the heat absorption to a minimum.

The difficulty with regard to the height determinations lies in the uncertainty of the zero of the trace and in slight irregularities of the calibration. From the measurement of the traces we obtain directly the amount by which the atmospheric pressure has fallen during the ascent. The difference between this and the barometric reading at the ground level gives us the residual pressure from which the height is computed. The pressure at the highest level is the difference between two large quantities and is consequently subject to a relatively considerable error. Further, at great altitudes the rate of change of pressure with height is very small. It follows, therefore, that the determination of the maximum height is always somewhat uncertain.

Curves giving the results of the five ascents are shown in the accompanying diagram (Fig. 2).

The ascents confirm the interesting theory put forward by Teisserenc de Bort[1] with regard to the existence of a nearly isothermal layer above some 7 miles.

Between the ground-level and a height of about 5 miles the temperature falls continuously. The average gradients over this range varied during the week between 0°·28 and 0°·33 per 100 ft. (0°·5 and 0°·6 C. per 100 metres). Above 7 miles all our curves show a more or less marked temperature inversion.

To what extent these and the other features of the curves may depend on local circumstances or even on instrumental errors can only be determined when the results obtained at the other stations have been worked out.

Pending the publication of the complete observations it is of course useless to attempt any general discussion of the subject.

[1] *Comptes Rendus*, vol. 134, pp. 987-1000, April 1902. Vol. 138, pp. 42-45, Jan. 1904. Vol. 145, pp. 149-152, July 1907, etc.

III.—BALLOON EXPERIMENTS IN DUBLIN, JULY 22-27, 1907.

By Prof. W. E. THRIFT, M.A., Trinity College, Dublin.

It was proposed to observe the balloons from Trinity College, Dunsink Observatory, and Mountjoy Square, the observations made at the third station being intended to check those made at the others.

Unfortunately the weather throughout the week could hardly have been worse for the purpose, as it was almost invariably thick and cloudy. There was a slight improvement on Friday afternoon in the suburbs, so Ashtown Racecourse was substituted for the city stations. It is near Dunsink, between Dunsink and the Phœnix Park, which lies to the west of the city. On Friday two stations were chosen on a straight stretch of the racecourse which runs nearly east and west. These stations were about five-eighths of a mile apart; the west one being in full view of Dunsink Observatory, distant about half a mile from it. However, probably because their telescope could not be depressed below an altitude of a few degrees, and because the Observatory is on a hill, the Dunsink observers did not get in view in their telescope the balloons sent up from Ashtown, so that observations on them were only taken from the Ashtown stations. On Saturday afternoon, July 27, owing to scarcity of observers, only one station was used at Ashtown. Balloons were sent up both from Ashtown and from Dunsink Observatory: observations on the latter were taken from both stations.

Two balloons a day, at least, were sent up, despite the fact that little was to be expected from the direct observation of them because of the thickness of the atmosphere, as it was hoped that information might be gained from their ultimate destination, which was regarded as the primary object of the experiments. Of the earlier ones, several had obviously insufficient lifting power, even though I had considerably exceeded the suggested degree of inflation. I was at first afraid to inflate them more lest they should burst before reaching any considerable height. Direct experiment on one balloon showed what degree of expansion that particular kind of balloon was capable of, and it was easy then to calculate, approximately at any rate, what inflation was permissible with a given rise in view. It will be noticed that with one exception all the balloons, of the finding of which I have been notified, were found near Dublin, and that they were the ones with very little lifting power. In fact the condensation of moisture on them was probably sufficient to bring them down. The exception had good lifting power and crossed the Channel, falling in Wales. The direction of the upper current was therefore, on this occasion, North-West, though that of the lower was South-East. Most of the other balloons probably fell in the Channel.

I think that possibly interesting information may be obtained from experiments 15, 16, and 19, with regard to the rate of ascent question.

I can determine the positions of the various stations, from observations taken at them, to a fair degree of accuracy, if they are required.

The balloons were generally lost sight of owing to their disappearance in clouds.

Professor Whittaker, his assistant Mr. Martin, Mr. G. T. M'Caw, of the Geodetic Survey, N.E. Rhodesia, my assistants Mr. Jackson and Mr. Cotter, and three of our students, Mr. Poole, Mr. Hill, and Mr. Panton, took important parts in the carrying out of the experiments.

I think the method adopted quite satisfactory and capable of successful application if large balloons are used, and proper arrangements made with regard to stations and observing instruments. I found the best way of conducting the observations was to have one observer at the observing telescope, and two others at the measuring circles. The former kept the

Balloon Observations made at Dublin.

No. of Experiment.	July.	Time.	Height of Barometer uncorrected.	Temperature Dry Bulb.	Temperature Wet Bulb.	Wind Lower.	Wind Higher.	Weather.	No. of Letter.	Description of Balloon, unextended diameter. ins.	Inflated Circumference.	Weight of Balloon in grams.	Lifting Power in grams.	Observations taken.	Place found.	Where released.	Time seen at release station.
		hrs. min. sec.	ins.	°	°						ins.						min. sec.
1	22	9 3 30 A.	30·012	59·9	58·1	NE	...	Dark. Sky overcast with clouds. Mist at intervals	1	7⅛	44½	13·9	14·2	One at T.C.D. station (A)	?	Park, T.C.D.	1
2	23	9 10 0 A.	29·954	56·0	55·5	ENE	...	Raining slightly	2	6½	38	13·9	2·0	...	Holywood Rath, Co. Dublin	Park, T.C.D.	1 55[1]
3		Tested balloon similar to above by inflation with bellows. It burst at							69 ins.	circumference.							
4		Strip of rubber 1 in. wide broke under pull of 1500 grams.															
5		Inflated balloon, as in No. 1, lost 1 gram lifting power in 33 minutes.															
6		Inflated balloon, as in No. 1, released in room did not fall for 7 hours.															
7	23	5 0 0 P.	29·978	...	...	E	...	Dull. Cloudy	3	7	44	13·7	9·8	17 at T.C.D. station (B)	?	Park, T.C.D.	7 45
8	24	10 0 0 A.	30·006	58·1	55·7	E	...	Dull. Cloudy	4	7	41	14·0	6·5	11 at T.C.D. station (C)	?	Park, T.C.D.	3 40
9	24	4 16 0 P.	30·026	...	...	E	...	Dull. Cloudy	5	4½	31½	7·0	3·0	...	Clondalkin, Co. Dublin	Park, T.C.D.	6
10	25	9 30 0 A.	29·998	59·0	55·2	ESE some low smoke from ENE	...	Bright through clouds. No clear sky	6	7	41	13·5	7·0	Several at T.C.D. station (D)	?	Park, T.C.D.	4 58
11	25	10 16 30 A.	...	...	...	...	...	...	7	Large Fire Balloon	...	...	...	Several at T.C.D. One at Mountjoy Sq. (E)	Tallaght, Co, Dublin	Phys. Lab., T.C.D.	8 30
12	25	6 8 0 P.	29·991	...	...	SE	NW	Cirrus clouds. High with some low	8	24	(?)110	331·8	95·2	One at Mountjoy Sq. Several at T.C.D. (F)	Llandilafawr, Breconshire	Park, T.C.D.	13 15
13	26	9 5 0 A.	29·890	64·2	60·4	SE	...	...	9	11	68	87·9	1·0	At Mountjoy Sq. and at T.C.D. (G)	Drumcondra, Co. Dublin	Park, T.C.D.	7 15[2]
14	26	11 0 17 A.	...	...	...	...	...	...	10	13	84	86·7	93·2	At T.C.D. (H)	?	Park, T.C.D.	3 43
15	26	12 0 0	...	...	...	...	...	...	...	6¾	62	29·2	42·7	Two stations T.C.D. (I)	...	Park, T.C.D.	3 25[3]
16	26	5 46 0 P.	...	...	...	NW	...	Fair, but clouds present	11	6¾	62	29·2	42·6	Two stations Ashtown (J)	?	Ashtown, W. station	8 47
17	27	9 0 0 A.	29·968	62·1	57·0	SW	...	Cloudy . .	12	6¾	53	29·1	15·2	At T.C.D. (K)	?	Park, T.C.D.	4 12
18	27	4 58 ·7 P.	...	...	...	WSW	...	Fair. Few clouds	13	12	77	87·5	46·7	At Ashtown (L)	?	Ashtown .	9 43
19	27	5 14 0 P.	...	...	...	...	...	...	14	6¾	60	29·2	36·2	At Dunsink & Ashtown (M)	?	Dunsink Observatory	19 30

[1] Inflation advised, but obviously insufficient. Feared bursting on rising, therefore tried following experiments.
[2] Stopped inflation because expanded unevenly, developing a very thin spot. Only sent up because of arrangement as to time with other stations.
[3] This balloon was sent up in order that direct observations on its rate of ascent might be made from two stations.

balloon always in view; on bringing it to the intersection of cross wires, he called to the other observers who noted the time and the readings of the horizontal and vertical circles; they generally had time to take their readings before the observer at the telescope was obliged to move the telescope in order to prevent the balloon going out of the field of view. In this way the balloon could be followed till it appeared as a very small speck in the telescope—so small that it would have been quite impossible to find it again, if once lost sight of by the observer.

The Dispersal of Fog.

Some time ago Dr. Shaw, the Director of the Meteorological Office, at the invitation of the London County Council, consented to examine and report upon the proposals of Signor Demetrius Maggiora "to prevent the formation of fog, or to disperse it in case it is already formed, and also to disperse and destroy all clouds, and to prevent rain, hailstorms, lightning, and thunder."

In his report to the Public Control Committee Dr. Shaw stated:—

"The apparatus which Signor Maggiora now offers for removing London fog is apparently on similar lines to that supplied in Italy for dispersing hail-storms. From the scientific point of view hail affords a much more specious opportunity for human interference than fog. The atmosphere is then in a state of great commotion preceded by abnormally unstable conditions. A London fog is incidental to conditions of unusual stability, and Signor Maggiora's memorandum suggests no physical process which could produce any effect in accordance with the known physical properties of the atmosphere.

"It may be remarked that the weight of a cubic mile of air is about five million tons, and consequently the weight of fog-laden air, in the case of a fog a mile thick extending over the district of greater London alone, is 3000 million tons. It is obviously useless to attempt the motion of so great a mass by mechanical action. . . .

"I may sum up by saying that the claim to prevent or disperse fog is entirely unsupported by any evidence. The claim to prevent rain is opposed by the more frequent claim of similar processes to produce rain in countries which suffer from drought, and the claim to affect hail-storms (which is associated with that regarding thunder and lightning) is not allowed by the scientific experts of Austria and Italy who have conducted special investigations on the subject for their respective Governments."

Having regard to the terms of Dr. Shaw's report, the Committee made the following recommendation to the London County Council, which was agreed to:—"That the Main Drainage Committee be authorised to allow Signor D. Maggiora the use of a site, on land held for main drainage purposes, in order to enable him to conduct experiments with his apparatus for the prevention and dispersion of fog, and that the grant of any such facilities to Signor Maggiora shall be made on the distinct understanding that the experiments are not being carried out under the direction of the Council, and that the name of the Council shall not be used in any way in connection with any application for financial aid for working the invention."

DISCUSSION OF THE METEOROLOGICAL OBSERVATIONS AT THE BRITISH KITE STATIONS, SESSION 1906-1907.

By MARGARET WHITE, T. V. PRING, AND J. E. PETAVEL, F.R.S.

[Read November 20, 1907.]

Introduction.

Investigations of the upper air are carried out at four British Stations by means of kites and balloons.

These stations are—

1. Pyrton Hill, near Watlington, Oxon, 500 ft. above sea-level.
2. Ditcham Park, near Petersfield, Hampshire, 400 ft.
3. Brighton, Sussex, 380 ft.
4. Glossop Moor, Peak District, Derbyshire, 1100 ft.

The work is under the general direction of Mr. W. H. Dines, F.R.S., who has devised most of the special apparatus in use.

The present paper consists of an analysis of the records obtained during the past session.

The kites carry meteorographs which give a continuous record of temperature, wind velocity, humidity, and height. Some 5000 readings have been obtained from these records and form the principal basis of the following conclusions.

Temperature Gradients.

Under ordinary circumstances the atmospheric temperature decreases continually with increasing height. The rate of fall is, in the daytime, very rapid close to the ground and diminishes at higher levels.

The average temperature gradient calculated from the data published during the present session is given in the following table :—

TABLE I.—Temperature Gradients (Degrees Fahr. per 100 feet) in Various Parts of England. Average Values, Session 1906-1907.

Place	Ground—1640 ft.	1640-3280 ft.	3280-4920 ft.	4920-6560 ft.
Glossop Moor . . .	0°·68	0°·50	0°·34	0°·18
Brighton	0·44	0·30	...	...
Ditcham Park . . .	0·58	0·41	...	...
Oxshott and Pyrton Hill .	0·43	0·41	0·36	...

The decrease of temperature is somewhat more rapid at Glossop Moor and Ditcham Park than in the case of the other two stations. The average temperature gradient for all stations works out at 0°·50 per 100 ft. (0°·92 C. per 100 metres) between the ground-level and 1640 ft. (500 metres), 0°·42 (0°·76 C.) between 1640 and 3280 ft. (500 and 1000 m.), and 0°·34 (0°·61 C.) for the next 1640 ft. (500 m.).

In Fig. 1 the average temperature height curves for the various stations are given. For the purpose of comparison curves embodying the

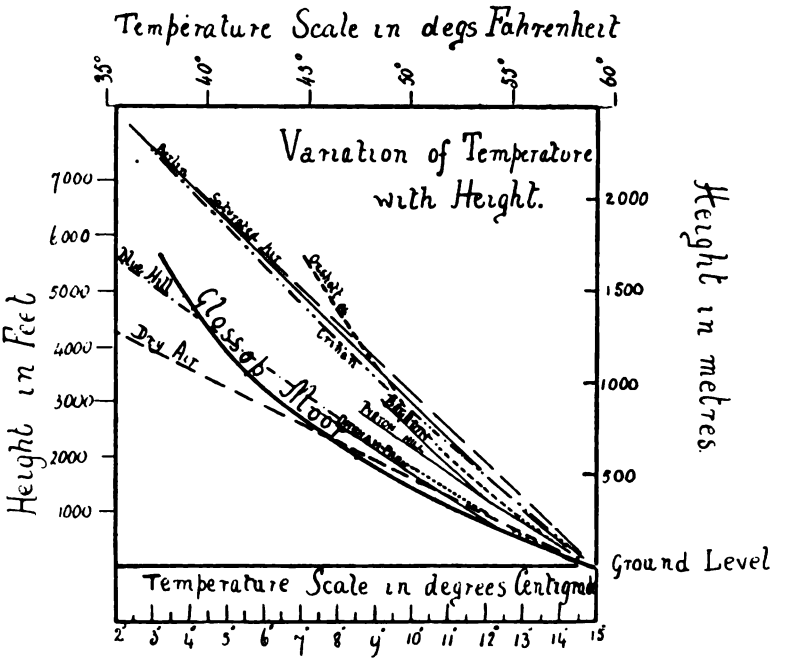
Temperature Scale in degs Fahrenheit
35°
40°
43°
50°
55°
60°
Variation of Temperature with Height.
Height in Feet
7000
6000
5000
4000
3000
2000
1000
2000
1500
1000
500
Height in metres.
Ground Level
Glossop Moor
Dry Air
Temperature Scale in degrees Centigrade
2°
3°
4°
5°
6°
7°
8°
9°
10°
11°
12°
13°
14°
15°

FIG. 1.

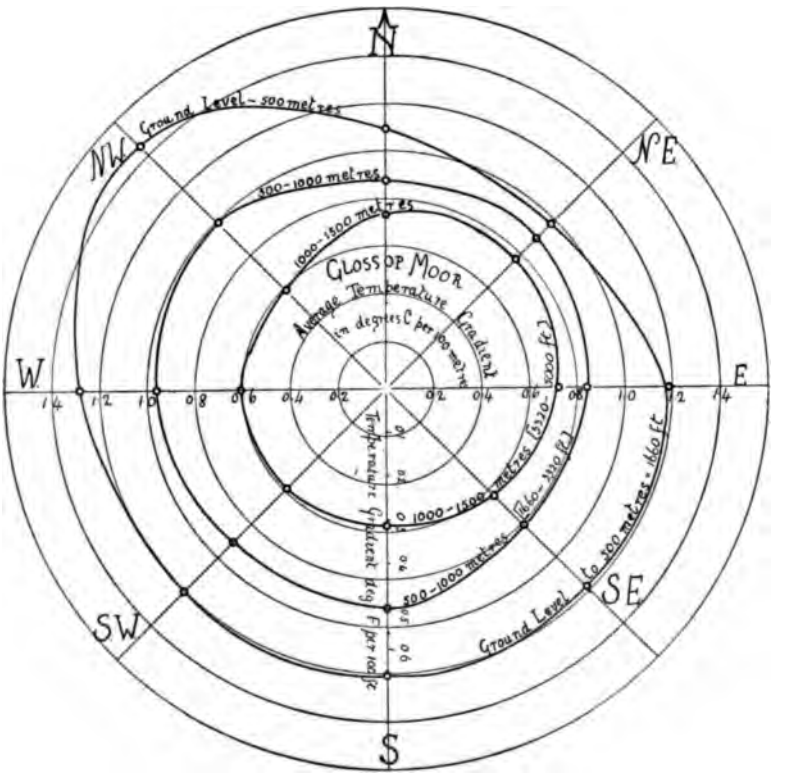
N
NW
NE
W
E
SW
SE
S
Ground Level - 500 metres
500-1000 metres
1000-1500 metres
GLOSSOP MOOR
Average Temperature in degrees C per 100 metres Gradient
Temperature Gradient deg F per 100 ft
1000-1500 metres (3320-5000 ft)
500-1000 metres (1640-3320 ft)
Ground Level to 500 metres (1640 ft)

FIG. 2.

results obtained at Blue Hill,[1] Berlin,[2] Oxshott, and Crinan during previous years are inserted.[3]

The theoretical fall of temperature due to the adiabatic expansion of dry and also of saturated air will be found on this diagram.

The Berlin, Crinan, and Oxshott curves agree closely with the calculated gradient for saturated air, whereas the Blue Hill and Glossop Moor curves lie closer to the dry air values.

Let us now consider what factors might *a priori* be expected to cause a departure from the above-stated average conditions.

Firstly, the temperature gradient varies with the direction of the wind. At Glossop Moor it is largest for a North-west wind, as will be seen in the polar diagram (Fig. 2).

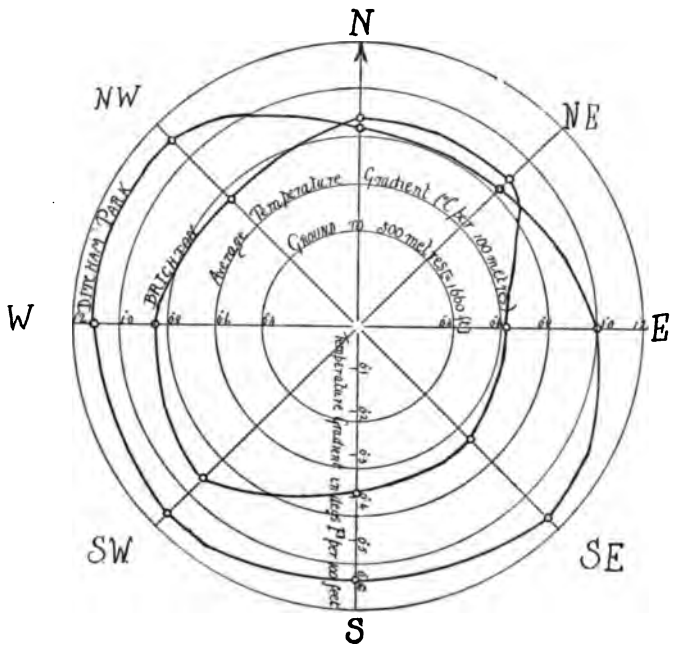

FIG. 3.

The distribution at Brighton and Ditcham Park is shown in Fig. 3. At Oxshott and Pyrton Hill both the change of gradient with height, and the variation with wind direction, as calculated from this session's observations, are very small.

Numerous observers have noticed that in a general way the temperature gradient is highest on fine cloudless days, and lowest when the sky is overcast.

This led us to calculate the average temperature gradient at Glossop for a high and for a low barometric pressure, with the following result:—

[1] See Dines, *Proc. Roy. Soc.* vol. lxxvii. p. 443.

[2] *Met. Zeit.*, 1904, p. 459.

[3] See also for Paris, St. Louis, Blue Hill, Berlin, and Moscow, *Beitr. z. Phys. d. freien Atmos.*, 1906, vol. ii. p. 40.

TABLE II.—Average Temperature Gradient for High and Low Barometric Pressures (Degrees Fahr. per 100 feet).

	Ground-1640 ft.	1640-3280 ft.	3280-4920 ft.
Barometer above 30 inches . .	0°64	0°41	0°45
,, below 30 inches . .	0·59	0·41	0·31

The difference is small but seems to bear out the statement. If, however, we take as our criterion the actual percentage of clouded sky during the ascent we obtain a much more definite result.

TABLE III.—Temperature Gradient at Glossop on Cloudless and on Overcast Days (Degrees Fahr. per 100 feet).

	Cloudless or almost cloudless sky.	Sky partly clouded.	Sky entirely overcast.
Ground-1640 ft.	0°91	0°84	0°51
1640-3280 ft.	0·60	0·55	0·39
3280-4920 ft.	0·33 (?)	0·28	0·27

With a cloudless sky, therefore, the average temperature gradient is always large.

This effect is doubtless due to the difference between the adiabatic expansion of dry, saturated, and partly saturated air; and this conclusion is borne out by a comparison between the percentage of humidity corresponding to the average of the highest and lowest temperature gradients.

TABLE IV.—Temperature Gradient and Humidity, Glossop, 1906-7 (Degrees Fahr. per 100 feet).

	Gradient.	Corresponding Average Humidity. %
Ground-1640 ft. . . .	0°99	77
	0·45	91
1640-3280 ft.	0·63	82
	0·36	94
3280-4920 ft.	0·46	79
	0·17	94

The observations were also analysed in order to estimate the connection between the wind velocity and the temperature gradient. Taking for each height the average, firstly of the lowest and then of the highest temperature gradients, we obtain the following result:—

TABLE V.—Wind Velocity and Temperature Gradients.

Temperature Gradient in degrees Fahr. per 100 ft.; Wind Velocity in miles per hour.

Place.	Ground-1640 ft.		1640-3280		3280-4920	
	Temp. Gradient.	Wind Velocity.	Temp. Gradient.	Wind Velocity.	Temp. Gradient.	Wind Velocity.
Glossop Moor . .	0°45	17	0°36	28	0°17	35
	0·99	15	0·63	24	0·46	31
Ditcham Park . .	0·38	30	0·35	30	...	...
	0·73	26	0·52	28	...	...
Brighton . . .	0·13	20	0·09	29	...	...
	0·71	22	0·49	24	...	...
Oxshott . . .	0·22	22	0·12	28	...	...
	0·65	19	0·54	34	...	...

There is, it appears, little doubt that a strong wind and a low temperature gradient usually co-exist.

The results obtained near Paris, Blue Hill, and Berlin, show a considerable variation of temperature gradient from summer to winter;[1] this effect exists in England but it is much less marked.

TABLE VI.—Average Temperature Gradient in Summer and Winter (Degrees Fahr. per 100 feet).

	Ground-1640 ft.	1640-3280.	3280-4920.
Average for England.			
Summer	0°59	0°47	0°38
Winter	0·46	0·38	0·24
Average for Berlin.			
Summer	0·60	0·38	0·36
Winter	0·13	0·15	0·16

The result of this relatively slight alteration of the gradient with the season of the year is to render the curves of temperature nearly parallel at all heights, as, for instance, is shown in the case of Glossop in Fig. 4.

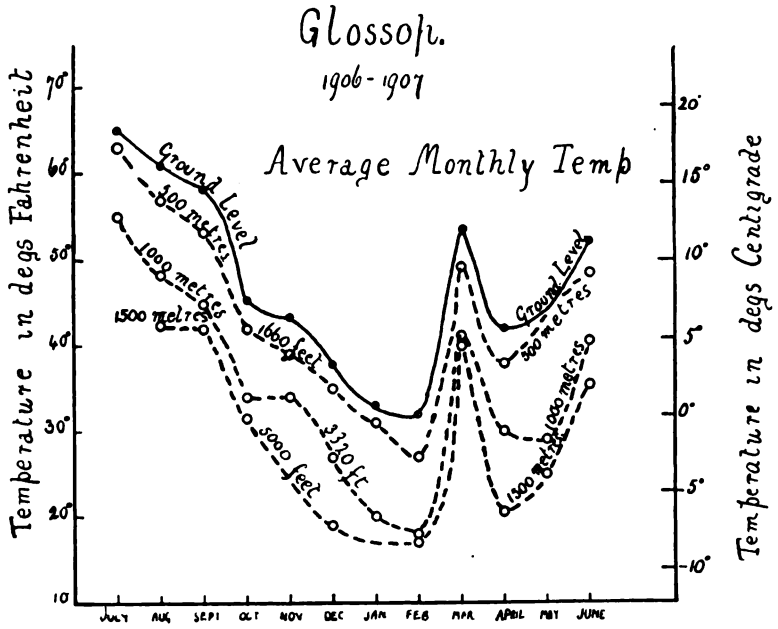

Fig. 4.

Wind Velocities.

A serious defect of the investigation by means of kites is that the conditions under which observations can be taken are limited; a calm or, on the other hand, a very stormy day rendering a successful ascent impossible.

To obviate this defect it is hoped in subsequent years to provide for

[1] See *Beitr. z. Phys. d. freien Atmos.*, 1906, vol. ii. p. 35.

the use of balloons on calm days, while the recent installation at Glossop Moor of new machinery, purchased with funds awarded by the Government Grant Committee of the Royal Society, will, it is hoped, considerably increase the chances of a satisfactory ascent in very high winds.

In Table VII. the average wind velocities at various heights have been worked out from the results obtained at each of the kite stations.

TABLE VII.—Average Wind Velocities (Miles per hour).

Place.	Ground.	1640 ft.	3280 ft.	4920 ft.
Glossop Moor	13·0[1]	26·1	30·2	33·3
Oxshott and Pyrton Hill . .	13·0	30·0	31·8	36·7
Brighton	16·1[1]	26·6	28·5	...
Ditcham Park	24·7	29·5	31·2	37·5 (?)

[1] Estimated.

The average wind velocity at each height is therefore nearly the same at all stations. It has been pointed out that these numbers do not include all possible weather conditions; but as the maxima and minima wind velocities happen to be both excluded by experimental difficulties, the error is to a certain extent compensated. The rate of increase is, however, probably somewhat exaggerated, owing to the fact that the higher altitudes are attained only when the upper wind is of considerable strength.

The average wind velocity increases with height very rapidly for the first 330 ft. and more slowly at higher levels.

At the Blue Hill Observatory the increase in velocity with height is 0·6 mile per hour in summer, and 2·1 miles per hour in winter for each 330 ft. rise.

In England, near to the ground level, a similar change occurs, the winds in winter increasing twice as rapidly as in summer. At heights above 1640 ft. the gradient still alters with the season. The variation, however, is in the reverse direction, the increase in winter being 0·9 mile per hour per 330 ft., falling in the summer months to 0·6 mile per hour.

It has been suggested by Clayton and by Egnell[1] that the wind velocity at any altitude is inversely proportional to the density of the atmosphere at that altitude; that is to say, the mass of air passing a given point in a given time is constant for all altitudes, or, expressed algebraically,

$$Vd = \text{constant}$$

where V is the wind velocity and d the density of the atmosphere.

The law applies well for high levels, but at the moderate heights reached by kites the increase is rapid, and follows more closely the inverse square of the density.

We now come to the question of the alteration of wind direction with height. As is well known from the study of the motion of clouds, and from the data obtained by means of balloons, the direction of the wind alters at high levels, rotating in a clockwise direction; for instance, a South wind tends to become more Westerly.

In individual experiments the amount, and even the direction of the rotation, differ widely. Taking, however, averages from the 600

[1] *Comptes Rendus*, 1903, vol. cxxxvi. pp. 358-361.

observations of wind direction, which are available for the present session (balloon ascents included), we obtain a consistent result, showing that up to 8200 ft. the angle between the wind at the ground level and the upper wind is nearly proportional to the height.

Height.	Total angle of rotation.
Ground to 1640 ft.	11°
,, 3280 ,,	18°
,, 4920 ,,	20°
,, 6600 ,,	30°
,, 8200 ,,	40°

Previous investigations have shown that both under cyclonic and anticyclonic conditions the change of direction is greatest in the case of a Southerly wind. Taking from our observations the average rotation for such winds we obtain angles of 13°, 35°, and 67° between the wind at the ground level, and at 1640, 4980, and 8200 ft. respectively, *i.e.*, a rotation nearly 50 per cent. above the general average.

The investigation of the relation between wind velocity and barometric gradient may not seem at first sight to offer serious difficulties. In

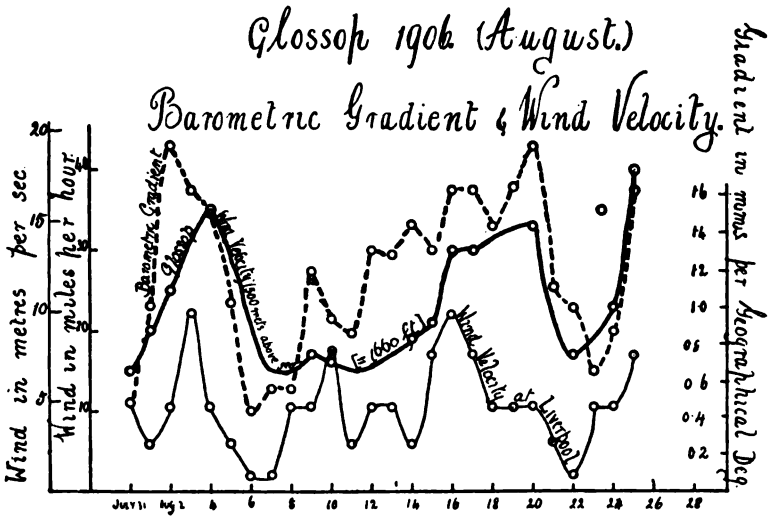
Glossop 1906 (August.)
Barometric Gradient & Wind Velocity.
Wind in metres per sec.
Wind in miles per hour.
Gradient in mms per Geographical Deg.
Barometric Gradient Glossop
Wind Velocity 1640 feet above
Wind Velocity at Liverpool

FIG. 5.

Fig. 5 the gradients and resulting wind velocities, as measured at Glossop during August 1906, are plotted, and the synchronous rise and fall of the curves is at once apparent. It is equally evident that the wind velocity cannot be expressed as a simple function of the gradient. Theoretical considerations confirm this view. The wind velocity depends, not merely on the absolute value of the gradient, but on the angle which the wind forms with the direction of the gradient, on the curvature of the path, and doubtless also on the wind direction, season of the year, and other factors.

A preliminary study of the question showed that the data available were too incomplete to form the basis of reliable conclusions.

The exact gradient at the time at which the observations are taken cannot be obtained with accuracy; the general disposition of the isobars over the country is recorded morning and evening by the Meteorological Office, but it is only by interpolation that the gradient at any other time of day can be determined. Again, small local variations in barometric pressure cannot be obtained from the weather charts, but have probably an important effect on the prevailing wind.

It would be useless to give a further account of this incomplete and therefore unsatisfactory part of our work.

During the coming year it is hoped to arrange for barometric observations to be made, during the kite ascents, at various places in the neighbourhood of the Glossop Station, with a view to the further study of this question.

APPENDIX.

The values given in Tables I.–VII. are reproduced in the Centigrade and Metric scales in the following Tables for the use of Continental observers :—

TABLE I.—Temperature Gradients (Degrees Centigrade per 100 metres) in various Parts of England. Average Values for the Session 1906-1907.

Place	Ground level-500 metres.	500-1000 metres.	1000-1500 metres.	1500-2000 metres.
Glossop Moor . . .	1°24	0°91	0°61	0°33 (?)
Brighton	0·81	0·54	...	...
Ditcham Park . . .	1·05	0·75	...	...
Oxshott and Pyrton Hill .	0·78	0·75	...	...

TABLE II.—Average Temperature Gradient for High and Low Barometric Pressure (Degrees Centigrade for 100 metres).

	Ground-500 metres.	500-1000 metres.	1000-1500 metres.
Barometer above 762 mms. . .	1°17	0°75	0°81
Barometer below 762 mms. . .	1·08	0·75	0·56

TABLE III.—Temperature Gradient at Glossop on Cloudless and on Overcast Days (Degrees Centigrade per 100 metres).

	Cloudless or almost cloudless sky.	Sky partly clouded.	Sky entirely overcast.
Ground-500 metres . .	1°66	1°53	0°93
500-1000 metres . .	1·09	1·00	0·72
1000-1500 metres . .	0·60 (?)	0·51	0·49

TABLE IV.—Temperature Gradient and Humidity, Glossop, 1906-7 (Degrees Centigrade per 100 metres).

	Gradient.	Corresponding Average Humidity.
		%
Ground-500 metres . . .	1°80	77
	0·82	91
500-1000 metres . . .	1·14	82
	0·65	94
1000-1500 metres . . .	0·83	79
	0·31	94

TABLE V.—Wind Velocity and Temperature Gradients.

Temperature Gradient in degrees Centigrade per 100 metres; Wind Velocity in metres per second.

Place.	Ground-500 metres.		500-1000 metres.		1000-1500 metres.	
	Temp. Gradient.	Wind Velocity.	Temp. Gradient.	Wind Velocity.	Temp. Gradient.	Wind Velocity.
	°	m.p.s.	°	m.p.s.	°	m.p.s.
Glossop . .	0·82	7·6	0·66	12·5	0·31	15·6
	1·805	6·7	1·13	10·7	0·84	13·8
Ditcham Park .	0·695	13·3	0·645	13·1	...	...
	1·325	11·6	0·943	12·5	...	...
Brighton . .	0·232	8·9	0·168	13·1	...	...
	1·297	9·6	0·890	10·7	...	...
Oxshott . .	0·394	9·8	0·186	12·3	...	...
	1·188	8·3	0·980	15	...	...

TABLE VI.—Average Temperature Gradient in Summer and Winter (Degrees Centigrade per 100 metres).

	Ground-500 metres.	500-1000 metres.	1000-1500 metres.
	°	°	°
Average for England.			
Summer . . .	1·08	0·86	0·70
Winter	0·84	0·69	0·43
Average for Berlin.			
Summer . . .	1·09	0·69	0·65
Winter	0·24	0·27	0·30

TABLE VII.—Average Wind Velocities (Metres per second).

Place.	Ground.	500 metres.	1000 metres.	1500 metres.
Glossop Moor . .	5·8[1]	11·6	13·5	14·9
Oxshott and Pyrton Hill	5·8	13·3	14·2	16·4
Brighton . . .	7·2[1]	11·8	12·7	...
Ditcham Park . .	11·0	13·1	13·9	16·7 (?)

[1] Estimated.

DISCUSSION.

Mr. W. Marriott said that the Kite Committee had considered it desirable that balloon observations should be taken in Ireland. Sir John Moore had suggested that they should apply to Prof. W. E. Thrift of Trinity College, Dublin; and he, with the assistance of the Astronomer-Royal for Ireland and other gentlemen, had entered into the matter very heartily. The Kite Committee considered it not desirable to send up any meteorographs, as Dublin was so close to the sea. A number of pilot balloons were used, and arrangements were made for having two or three observers with theodolites, to get the altitude and rate of travel of the balloons. The great difficulty experienced was with the weather. The sky was covered with low cloud, in which the balloons were lost in less than a minute. Only one of the balloons had passed over the sea, and that fell in Wales. Most of the balloons fell near Dublin, and did not attain any great altitude. A great deal of interest had been aroused, and much attention given to the subject in Ireland.

Mr. C. J. P. CAVE said that he had sent up six balloons in July, of which four had been returned. He showed the temperature and height curves on a lantern slide. Some of the balloons sent up in the daytime showed an undue rise of temperature at the highest points reached. The balloon sent up on July 23 gave higher temperatures than usual, due perhaps to solar radiation, as the balloon was probably not ascending fast; it was leaking and was found intact next day floating in the Channel. A balloon sent up on the evening of July 24 went up to 52,500 feet (16,000 metres), and was watched with one theodolite for two hours. The sun set on the balloon 22 minutes later than it set on the ground. July 25 was the only day on which an ascent was made with an instrument other than that of Mr. Dines', one of M. Teisserenc de Bort's meteorographs being used. The balloon of July 27 was the only one sent up at night; it reached a height of 28,000 ft. (8500 metres), and the decrease of temperature was rather greater than in the other cases. He was very grateful to Mr. Dines for the instrument he had designed, as those used on the Continent were heavier and much more expensive. In the International ascents England headed the list for height with two ascents at Manchester of 69,000 feet (21,000 metres), and out of nine ascents of over 65,000 feet (20,000 metres) four took place in England.

Captain C. H. LEY said that his observations had been chiefly carried on with pilot balloons, of which he had sent up more than thirty. He had used a method different from the other methods, consisting of measuring the diameter of the balloon by wires in the diaphragm of a theodolite, and from that getting the range of the balloon. Observations of the altitude determined the vertical height and the horizontal distance. Most of the results had been plotted, and he was submitting a general report on them. They were interesting chiefly in the matter of velocities. They showed no steady velocity, and the average over a long run could give only fair results, but there were considerable and sharp variations. His results agreed generally with the few returns given by Mr. Dines' instruments of the temperature variations. When the velocity was fast the temperature gradient was slow.

Dr. W. N. SHAW remarked that it was not long ago since the investigation of the upper air had been put aside, on the ground that it was impossible in this country, and it was extremely gratifying to find, within a few years, that the upper air had been investigated by the ascent of about twenty-five balloons during a single week. A new system of observations had also been introduced by the method of pilot balloons and their examination by theodolites. Captain Ley had used this method with remarkable effect, and it promised to form the subject of an interesting paper at a later date. They had heard two sets of papers, the first connected with the international ascents in the last week of July, and the second concerning the general results of kite and balloon observations, comparing the results obtained at different stations in the British Isles during the year 1906-7. It was rarely that any one was found to discuss the observations made by other people, and they had to thank Mr. Petavel for so doing. Mr. Petavel had dealt with the results of the different kite stations by the method of mean values. When considering the observations returned to the Meteorological Office with Mr. Gold, he had thought it desirable to go behind this method, and to endeavour to make some pictorial representation of the results of the kite observations, in which the classification of the observations according to frequency was represented. The diagrams he had had prepared were included in a paper read before the Aeronautical Society last December. He showed four slides, which gave the results at Oxshott in the form of differences at successive steps of 500 metres (1640 feet) from the values at 500 metres above sea-level. Dr. Shaw then called attention to the confirmation which the recent experiments afforded to the existence of the stratosphere, a layer of air

above which there would only be a slight variation of temperature. This isothermal layer was found at about 10 kilometres (6·2 miles), and its existence was clearly proved by many ascents. The curves compared satisfactorily with the best of those obtained on the Continent. As to the origin of this layer there were different suggestions, among them the question as to whether the proportion of gases did not vary. M. Teisserenc de Bort had endeavoured to ascertain the facts by using vacuum tubes, which were opened and sealed automatically at great heights.

Mr. J. E. PETAVEL remarked that the high temperature gradients obtained at Glossop Moor over the first height interval were doubtless due to the altitude of this station, which is 1100 feet (345 metres) above the sea. The first gradient is therefore the difference of temperature per 328 feet (100 metres) over a height of 492 feet (155 metres) only as compared with an average interval of 1310 feet (400 metres) for other British stations. As is well known the gradient very near the ground level is always exceptionally great.

The PRESIDENT, in conclusion, said they would all unite in conveying their thanks to the authors of the reports, Mr. Dines, Mr. Petavel, Mr. Harwood, Prof. Thrift, and Miss White, through the gentlemen who had read the papers. Captain Ley's report would, he hoped, be heard on a future occasion. Time did not admit of further speaking, but he might add that the mean curves of the vertical temperature gradient in the air were reminiscent of the typical curves of the vertical temperature gradient in the ocean and in seas, the region of rapid change near the surface passing gradually into an isothermal (or as he had ventured to term it, a homothermic) layer. In terminating the meeting he announced that an interesting Model of a Climatological Station, prepared by Messrs. Negretti and Zambra, was being exhibited in the tea-room.

January 16, 1908.—The average height of these ascents is over 13,000 metres, and a region where the temperature change with height is trifling has been reached in 26 cases.

Hail Shooting in Italy.

In the United States *Monthly Weather Review* for August 1907, there is a Note by Professor Cleveland Abbe, in which he says that the references to this subject in previous volumes of that publication have abundantly shown the probability that there is no rational basis for the efforts made in Italy and France to break up thunderstorms and prevent injurious hail by some method of cannonading. Neither the noise, nor the smoke, nor the heat, nor the commotion produced by grand vortex rings can be expected to have any considerable influence on the enormous cumulus clouds from which hail and lightning proceed. This conviction is now confirmed by a report read before the Royal Academy of Sciences at Rome (Accademia dei Lincei), on December 2, 1906, by Senator P. Blaserna, who is also Professor of Physics in the Royal University at Rome, and President of the Accademia dei Lincei. In 1902 Professor Blaserna was appointed by the Italian Government president of a special commission to investigate the subject. A locality that had suffered extremely in previous years was chosen as the field of operations, viz. Castel-Franco in Venetia, and 222 cannon of the most approved special type manufactured by the Greinitz Company were established ; each of these sends up a vortex ring 13 feet in diameter, and one additional cannon sending up a vortex 45 feet in diameter was subsequently added. As these vortices failed to ascend higher than 200 or 300 yards they evidently had no effect on the clouds ; therefore a higher station, the Casa Aulagne di Monteux, was occupied, so that the vortex rings attained 1200 yards, but still no good results were perceived.

Then the Secretary for War and the manufacturers of pyrotechnics were appealed to. Of the latter, Marazzi, at Rome, succeeded in constructing bombs weighing 18 lbs. that were carried up to 2500 feet, where they exploded. During 1906, 250 broadsides were fired by the 222 cannon at Aulagne, and 60 of the Marazzi bombs were sent up, but still no good effects were perceptible. These negative results of a five years' campaign justify the commission in recommending that the Italian Government no longer encourage such expensive and useless work.

Audibility of Clock Bells.

In connection with Mr. Marriott's notes on sound (and the clock bell of St. Paul's Cathedral being heard at a distance), in the *Quarterly Journal of the Royal Meteorological Society*, vol. xx. p. 243, the following extract from *Notes and Queries* (November 16, 1907) is of interest:—

The great clock bell of St. Paul's possesses the peculiarity of sounding different notes from different positions and distances (of different degrees of audibility). The architect who superintended its recasting must have forgotten to provide a section, consequently the bell is "straight-waisted," which accounts for its *uncertain* sound. All curves in the section of a bell should be sections of a cone, and of the same cone. Probably (says Mr. Walter Scargill) the architect may have forgotten to read his Vitruvius, who shows that an architect must not be "music-deaf."

Influence of Temperature on the Iron Railway Viaduct at Crumlin.

Begun in 1853, the great viaduct in Monmouthshire was opened in 1857, but after its completion temporary difficulties were experienced owing to the expansion and contraction of so vast a body of ironwork, and the girders had to be supported on rocking links.

The records which were taken show a variation, owing to the difference of temperature, of $\frac{7}{16}$ of an inch in the length of the viaduct between 4.0 a.m. and 4.0 p.m. on June 12, 1861, a fine warm day following a cold damp night. The greatest difference in length aggregates over two and a half inches, the extremes occurring respectively on February 12, 1861, when the temperature was 32°, and on August 27, 1861, when the temperature was 90°, a difference of 58°.—*Great Western Railway Magazine*, October 1907.

The Furness Railway Wind-Gauge.

More than two years ago some allusion was made (*Quarterly Journal of the Royal Meteorological Society*, vol. xxxi. p. 189) to the wind-gauge erected in the neighbourhood of Ulverston to protect trains from risk in traversing a very exposed viaduct. A full description of this is now given in *The Railway Magazine* (October 1907, p. 337, *et seq.*) with an illustration. The apparatus is fixed at the west end of the Levens viaduct, and its actuating part consists of two boards, kept in a vertical position by springs, and the movements of which are shown on a chart by means of the customary pen and clockwork appliances. A pen is operated by either board according to the direction of the wind, and for greater exactitude of time, the chart paper, over sixty-five feet long, is perforated, the holes in the paper corresponding with studs in a clockwork wheel.

When the wind pressure reaches 32 lbs. to the square foot the spring boards referred to are adjusted to make an electrical contact, ringing bells in the signal cabins on either side of the viaduct, and when this occurs all trains are detained until the force of the wind moderates—any such interruption being telegraphed to the superintendent of the line. The apparatus is tested weekly. It has been at work since September 1903, and in February 1907 a velocity calculated as equivalent to 65 miles an hour was recorded.

THE POSSIBILITY OF A TOPOGRAPHY OF THE AIR BASED ON BALLOON OBSERVATIONS WITH SPECIAL THEODOLITES.

By Capt. C. H. LEY, F.R.Met.Soc.

[Read December 18, 1907.]

Part I

That meteorology has hitherto been held by many to be a nebulous science, in which only vague generalisations or general averages can be dealt with, is no reason for assuming that it must always remain so, and it is with the object of drawing attention to one of the branches of meteorological investigation, which promises a considerable extension in the future, that this paper has been written.

I refer generally to the investigation of variations in velocity and direction of wind in the great middle strata of the atmosphere, by means of balloons followed by special theodolites, and, when possible, carrying instruments; and in particular to the results of the diameter method as carried out in Herefordshire this past summer.

Site.—Herefordshire is well situated for balloon ascents, because it is bounded on all sides by relatively large areas of land surface, especially in the direction towards which the prevailing winds blow, viz. towards points between N. and S.E.

The actual site was at Sellack, about 3 miles N.W. of Ross, on the neck of a long promontory running to N.E., and bounded by the river Wye, which here makes a sharp S-shaped bend through rather hilly country (see Figs. 5, 9).

Diameter Method.—The method is based on the direct estimation of range of the balloon from its apparent diameter, as measured by cross-threads in a telescope.

In the system found most convenient the threads form two or more horizontal triangles, crossed by equidistant vertical threads. The breadth of the triangles at the points of crossing is accurately determined, and the balloon is fitted in to a triangle, its diameter being estimated from the position it occupies in the triangle in reference to the nearest fixed threads (see Fig. 1).

The range being thus determined, an altitude and azimuth are read, and the position of the balloon fixed and plotted on a map.

In practice it is difficult, except when the range is great and the apparent motion slow (*e.g.* until diameters are less than say 25 seconds), to keep a balloon for any length of time between the cross-threads. During this period continuous momentary estimations are made until the eye can accurately gauge the rate of decrease of diameter and becomes aware of its position of fit, when a reading is taken.

The judgment throughout is made rather by appreciation of the area and curvature of the figure of the balloon in relation to the tangential threads, than by any actual linear measurement (see Fig. 1).

Readings.—The following system was found the best for readings:—
Observer reads diameter in seconds, and Horizontal Arc to ¼ degree.
Assistant reads time to seconds, and Vertical Arc to minutes.
Before sending up a balloon the cross-thread constants were when

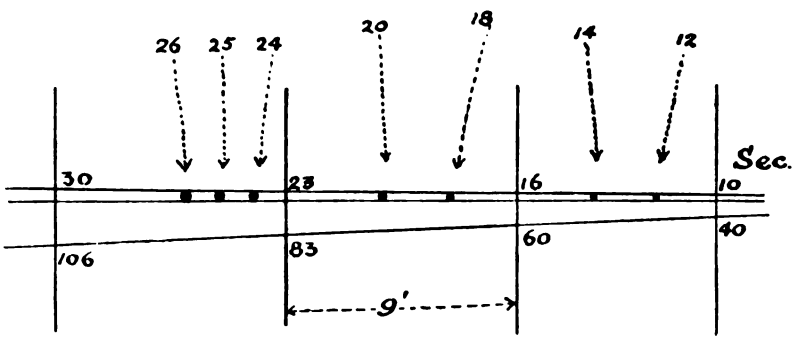

FIG. 1.—Cross-threads, showing Balloons.

NOTE.—Held 10 ins. from the eye, this diagram will appear of same size as the arrangement viewed with 45-power eye-piece.

possible checked on test points, the instrument accurately levelled and focussed, and the loss of gas in the balloon measured. In calculations all altitude angles were reduced to the centre.

Telescope.—The aperture was 1·9 inches, focal length 13½ inches.
Eye-pieces were used giving powers as follows:—

July	power 28
September	„ 40, 56
October	about 45

The 56 power was too high and bad definition resulted, but with 45 power the definition over the 26 minute distance occupied by the cross-threads was good.

Expansion Allowance.—The following expansion allowance, based on Boyle's law and an assumed decrease of temperature and pressure, was included in the theodolite calculations, and was considered accurate enough for practical purposes:—

0 – 5,000 ft.	0·9	per cent per 1000 ft. of height.
5,000 – 10,000 „	1·0	„ „ „
10,000 – 20,000 „	1·1	„ „ „
20,000 – 30,000 „	1·15	„ „ „

Solar Radiation.—To avoid solar radiation effect on gas as far as possible, as a rule the balloons were sent up shortly after sunrise or before sunset.

Rough experiments were made with thermometers placed inside coloured and colourless balloons in bright sunshine, filled with hydrogen and lung gases, which, though incomplete, tended to show that the solar effect in a colourless balloon at the earth's surface in the middle of a warm, still, dry day in the course of an hour is probably not great, but that the gas in a coloured balloon is much more powerfully affected. It seemed that the heating effect on the gas depends on the temperature

of the rubber, and that the warming of the latter is a comparatively slow process. It was thought, therefore, that the effect from solar radiation on the hydrogen, especially in a colourless balloon, is not sufficient at the sunrise and sunset hour in the middle strata to appreciably affect the accuracy of a diameter estimation.

Loss of Gas.—A sudden loss of gas would have to be large to affect the apparent diameter. Thus a 5 per cent shrinkage of diameter means a loss of 15 per cent in volume, which, if it occurred in a few minutes, would rapidly cause an unusual decrease in the observed altitude angle, and affect the subsequent gradients of track.

This, however, is not the case where apparently rapid shrinkages, resulting in high observed velocities, occur.

In most cases the decrease in the altitude angle is normal, in many it is a relative rise, and in some cases an actual and large rise takes place (see Figs. 4, 6, 7, 8).

There is, however, a fairly constant loss of gas in nearly all balloons. Although insufficient to affect the diameter in the short space of time under observation, in the case of No. 35 it had to be taken account of.

Flag Tests.—The only test as to accuracy of observations on balloons yet possible of application has been as follows:—

A light silk flag folded over a meridian of the balloon is kept in place by a silk tape running through itself and drawn tight over the flag and meridian. The circumference over the tape is accurately measured, and the free end cut off to any desired length according to the height. The diameters, and therefore volumes and pressures, at the start and at the moment when the flag drops are thus known, and the height can be calculated and compared with the height at that moment as calculated from the observed theodolite observations of the balloon, with the correction for expansion. This, of course, assumes a certain normal decrease of pressure and temperature.

This speculation resulted as follows:—

1907.	Balloon.	Theodolite height.	Flag do.	Difference per cent.
Sept. 12	31	13,706 ft.	13,383 ft.	2·4
Oct. 3	35	8,285	6,236	25
,, 4	36	7,247	6,924	4
,, 7	37	13,580	13,603	·17
,, 15	40	13,432	13,045	3

As will be seen below, No. 35 on October 3 was sent up in quite unusual conditions. Its measured loss of gas before starting was very large (6 ins. circumference in 55 minutes). This was allowed for in all theodolite calculations in this case. The large difference is not to be attributed to observational errors, as the balloon was very clear and steady at a large angle of elevation and the diameter large.

The analysis of the track (see Fig. 10) also shows reason for believing that sudden loss of gas is not a probable cause of the difference, especially as this balloon attained an altitude of nearly 60,000 ft.

There remain the possibilities of the tape having worked loose, or of a large variation from normal conditions.

I have no reason for believing the former. If, in the unusual general conditions referred to later, the latter was the case, the pressure at 8000 ft.

must have been that which would normally occur at 6000 ft., *i.e.* about 1·7 in. of mercury greater than the normal at this altitude.

With No. 40 on October 15 an improvement had been made by replacing the tape with a slack silk thread running through loops on the balloon and attached to a spring clip holding the flag. When the slack was taken in, and the thread pulled by the expanding balloon, the spring was released and the flag fell (see Figs. 2, 3). This arrangement would also be useful for dropping an instrument at a given height.

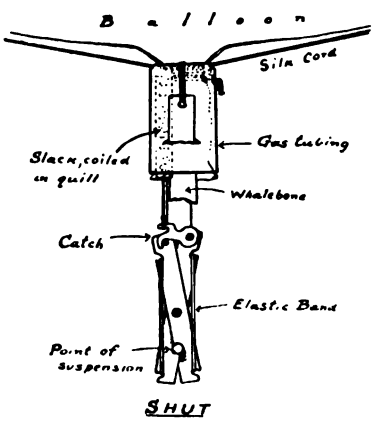

FIG. 2.

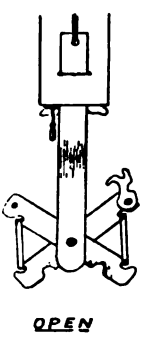

FIG. 3.

Formulæ used.—The formulæ used for theodolite calculations were as follows :—

$$\text{(i.)}\quad h = a\,\frac{(206085\ d \sin \mathrm{A})}{\mathrm{B}}.$$

$$\text{(ii.)}\quad h.d. = h \cot \mathrm{A}.$$

where

h = vertical height in feet.
$h.d.$ = horizontal distance in feet.
d = diameter in feet of balloon at start.
A = angle of altitude (to minutes).
B = observed diameter in seconds.
a = expansion percentage.

In the case of a flag-height calculation the formula used was :—

$$\frac{p}{\mathrm{P}} = \frac{\mathrm{V}}{v} \times \frac{273+t}{273+\mathrm{T}} \qquad \text{(Boyle's law)}$$

where p and P are the new and old pressures,
t and T „ „ temperatures
(t assumed from the theodolite height).

$\frac{\mathrm{V}}{v}$ was replaced by the fraction

$$\frac{\text{old circumference}^3}{(\text{old circ.} + \text{draw of tape})^3};$$

p was therefore ascertained, and the corresponding height obtained from the tables.

Formula connecting vertical velocity and lifting force:

$$L = \mu\rho r^2 v^2$$

where L = lifting force, ρ = relative density, r = radius of balloon, v = vertical velocity, μ = constant. If no loss of gas occurred, and relative densities remained the same, L is a constant. Also ρ varies as $\frac{1}{r^3}$,

Hence $$v \propto \sqrt{r}$$

Part II

Results.

Balloons were sent up as follows:—

July	21 Pilots	3 returned.
	3 Ballons Sondes	1 returned.
Sept. and Oct.	21 Pilots	13 returned.
	3 Ballons Sondes	3 returned.

Of the unreturned Pilots in September and October, several were seen to burst at comparatively low altitudes, and this was particularly the case with those that had been in store for some time.

The sizes used were as follows:—

1000 mm. C.T. Cos	1 Ballon Sonde
700 ,, ,,	4 Ballons Sondes
600 ,, ,,	1 Ballon Sonde
1000 ,, Paturel	2 Pilot Balloons
750 ,, ,,	9 ,, ,,
2 ft. coloured	18 ,, ,,
smaller English	16 ,, ,,

Several of the returned Pilot cards showed rapid probable velocities, notably Nos. 19A and 26. No. 26 was picked up at Stratford-on-Avon, 39 minutes after being lost to view.

Paturel's balloons were very efficient, and seldom lost gas to any extent.

July.—The July results were partly unsatisfactory, because a number of small, inefficient English balloons were used, the power of the telescope was only 28, the slow motion not perfect, and the cross-wires home-made of indiarubber solution. Wires of about 2 seconds apparent diameter could be obtained with the latter material, but only lasted a short time, and were subject to changes.

Thick wires, difficult to obtain otherwise, can, however, be made of indiarubber, and last well.

Except in 3 more accurate cases the July results have not been plotted. The results were sufficient, however, to confirm a suspicion entertained, *e.g.*, that local variations of velocity in the lower and middle strata are principally caused by undulations in the earth's surface.

The plans and sections, of which a few have been here reproduced, show the difficulty of accounting for these extraordinary variations by any mere theory of errors. Such a theory would have to assume a whole series of coincidences of great improbability.

Summary.—To summarise the results:

Tracks of 21 balloons have been plotted, and sectional drawings of the 18 longest courses made.

There appear 22 cases of balloons travelling at first over low ground, then over a definite ridge or hill, and in each of these cases the vertical velocity shows a considerable increase over the hill. In 9 of them the increase is over 100 per cent, and in the majority of the remainder over 50 per cent.

Two cases appear where there is a ridge but no rise in velocity, while there are 14 cases of a rise without any definite hill or ridge.

Of these 14 cases, 1 is certainly due largely to the effect of cloud, and was in North-west wind conditions; 4 occur with different balloons over the same locality in the neighbourhood of the Malvern Hills; 3 with different balloons over another locality presenting special features; 3 in North-west wind conditions; and the remainder at the beginning of runs in the lowest and most variable stratum of air, and when, owing to rapid apparent motion, errors are probably greater.

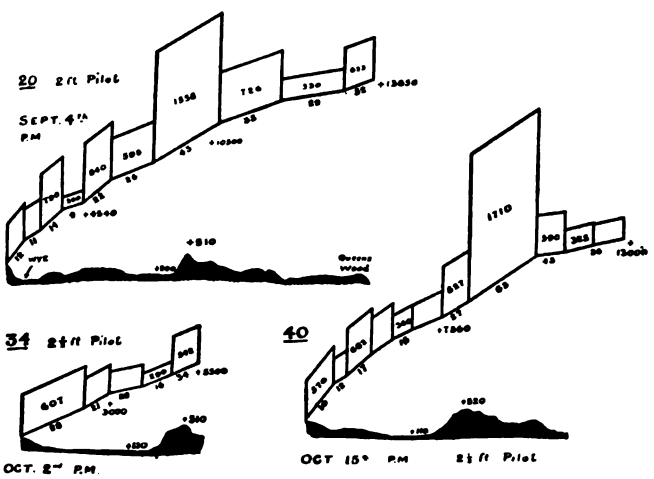

FIG. 4.

As a rule, over a hill both the vertical velocity and horizontal velocity increase, but the vertical velocity in greater proportion than the horizontal. On the other hand, over the lower ground before and after a hill it appears that the horizontal velocity usually increases faster, or shows a less decrease, than the vertical velocity, especially at the greater heights.

The ratio of the two components of velocity is of course shown by the slope of the track, which will be referred to below.

Horizontal Deflection.—The horizontal deflection of the wind due to the ground is much more marked when there is less wind, *i.e.* in anticyclonic conditions, in cyclonic calms, and at low altitudes. In such conditions the general tendency seems to be for the breezes to blow as far as possible along the contours of the ground. In the case of a valley the line of

least resistance is found along the bottom of the valley; in the case of a ridge this line is again along the contours; but there sometimes appears a breeze along and below the farther edge of the ridge, in a direction indicative of the general direction of the superimposed current (see Figs. 5 and 9).

Horizontal deflection is often accompanied by a collapse of vertical velocity (see Nos. 13, 35, 16, 20), and in the case of 16 this occurs with a very strong wind.

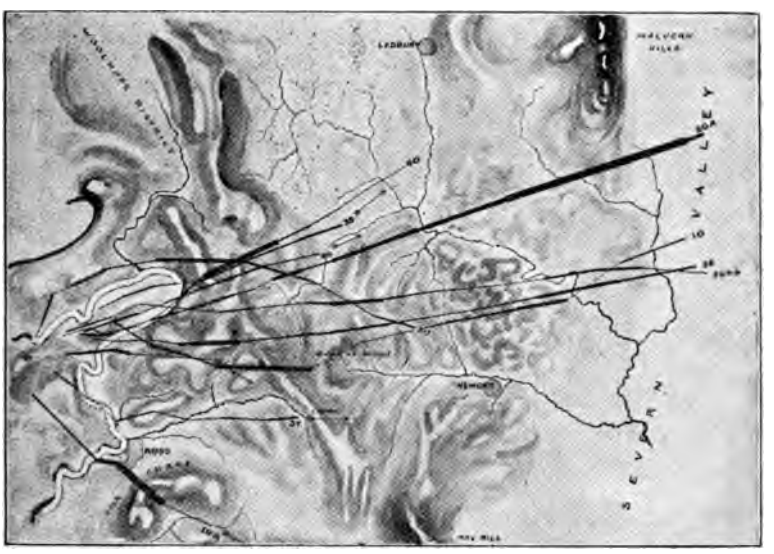

FIG. 5.

EXAMINATION OF EXCEPTIONS

Westerly Winds.—Exceptional Localities.—(i.) Between the Malverns and the lower slopes of May Hill lies a section of rough hilly country of no great height and cut through by several streams running down to the Severn.

The 4 balloons 16, 22, 24, and 26A passed over this section, and all showed remarkable and similar rises in velocity just before reaching the margin of the Severn valley (see Figs. 7 and 8).

With 26A, passing close to the Malverns at a height of about 18,000 feet, this increase was enormously magnified and evidenced by an actual rise in the angle of altitude (Fig. 8).

With 16, at a height of 8000 feet, the rise is followed by a drop over the further edge with a change in direction towards the Malverns, as had also been the case with the previous ridge.

With no definite hill immediately below to account for this, it seems likely that it is due to a lateral extension of the lift of air over the Malverns themselves, *i.e.* so to speak, to the flanks of a large "air-mountain" due to these steep hills. Supposing that May Hill and the

Forest of Dean formed another "air-mountain," the section of ground referred to would lie under a high "air-neck" joining the two supposed mountains.

The terms "air-mountain," "air-neck," etc., are only used, however, to illustrate the raising or depressing effect on a particle. The actual isobaric surfaces are, it is suggested later, possibly raised over the valley preceding a hill, and depressed over the high ground in a manner corresponding to an anticyclone and cyclone respectively.

(ii.) In the cases of Nos. 22, 24, 26A, again, there is a sudden increase of velocities over Queen's Wood and the Kempley ridge just north of this wood. This ground is higher than that just noticed, but less rough, and is the source of many small tributaries of the Severn. Its height does not quite account for the jump of balloon velocities over it in an air-stratum between 5000 and 8000 feet high.

It is noticeable, however, that this damp ground marks the western limit of the Old Red Sandstone on the border of a comparatively impervious wedge of shale and limestone forming the actual watershed and separating this district from the Old Red Sandstone in the Wye valley.

In the case of 40, to the north of this area, there is no rise in velocities, which are quite low, and in the case of 16, just south of this area, there is an actual drop in velocities with a change of wind to the North, as previously noticed.

It would seem that this locality forms a coll or "air-ridge" extending from the general air-ridge to the west and overlooking a broad "air-basin" to the north lying over the ground basin between the Marcle and Ledbury hills.

Exceptional Wind Conditions.—The 3 cases of exceptional rises in velocity over low ground with a North to West wind are 36, 19A, and 19.

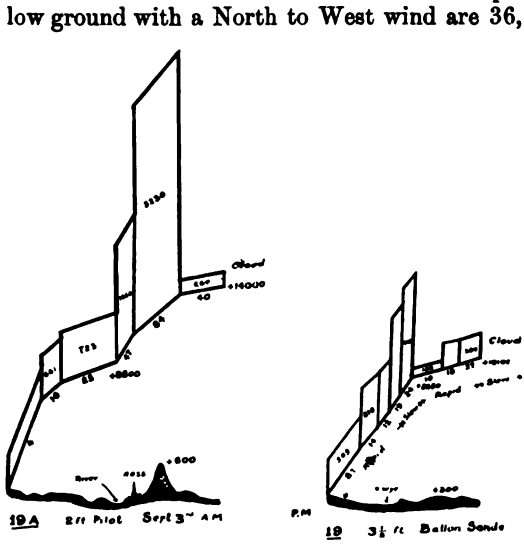

FIG. 6.

In these cases the exceptions occur in the lower and lower middle air strata, *i.e.* below 8000 feet.

19 and 19A (Fig. 6) were sent up on the same day, September 3. A deep depression was moving away to the north over Norway, and dispersing.

In the morning 19A showed unusually little breeze and low vertical velocity up to 6000 feet, followed by a strong middle current from North-west with rapid ascensional movement over Wye valley until the Ross Hills were reached, when the combined effect of the town and the steep hill caused the balloon to swerve and shoot up with enormous vertical velocity, this velocity immediately dropping over the sheltered valley beyond, when the balloon entered the stratus bank lying over the Forest of Dean area. It was picked up at Newbury in Berkshire the next day, 68 miles south-east of Ross.

In the evening another depression was appearing over Ireland, and the wind was backing to West. Again there was a comparatively mild breeze in the lowest stratum, but rapidly increasing at about 3000 feet, until just beyond the Wye valley, at the first ridge, when another extraordinary jump occurred, principally in vertical velocity, at a height of about 7000 ft., followed by a swerve and sudden drop to low but increasing velocity towards the watershed, where it entered the stratus belt at 10,000 ft. The balloon carried an instrument which was picked up at Lewes, in Sussex, about 135 miles to the south-east of Ross, after a maximum vertical run of 45,000 feet.

The two tracks are of similar nature in somewhat similar conditions, show a general North-west upper current, a change of wind in the lower stratum, and a general levelling process taking place during the day in the matter of horizontal velocity.

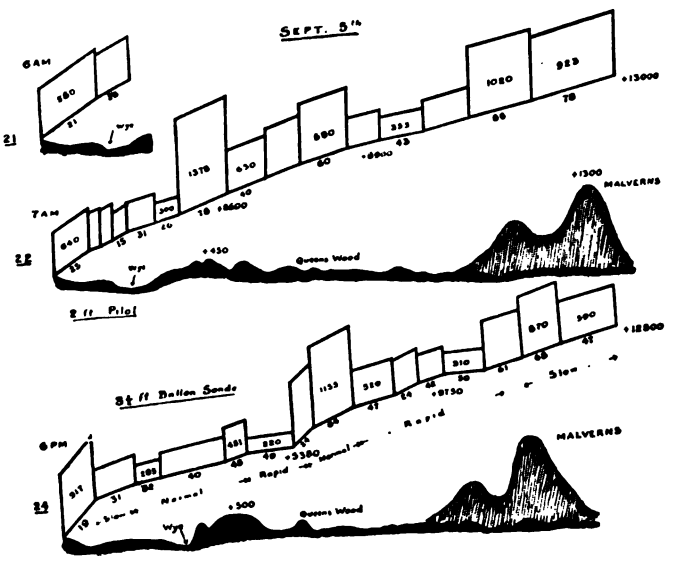

FIG. 7.

These diurnal effects should be compared with similar effects in the case of the three balloons 21, 22, 24, also sent up on the same day, viz.

September 5, with a deep depression moving across the north of Scotland (Fig. 7). No. 36 occurred in anticyclonic conditions with a strong Northerly breeze in lower stratum, decreasing somewhat in horizontal velocity with altitude. The balloon was picked up at Tidenham (15 miles), having probably followed the Wye Valley.

Exceptional Cloud Conditions.—No. 10 balloon, sent up on July 20, was lucky in escaping thick banks of composite cloud at a short break in the afternoon. Its vertical velocities are unusally high, and horizontal velocities low over low ground in the stratum between 5000 and 10,000 ft. There was again little wind in the lower stratum, but a light North-west breeze in the higher. The balloon, however, after the first period follows the valleys with accuracy. It was picked up by Mr. Dines about 6 miles south-east of Oxford, after having attained a height of 67,000 ft. (Fig. 9).

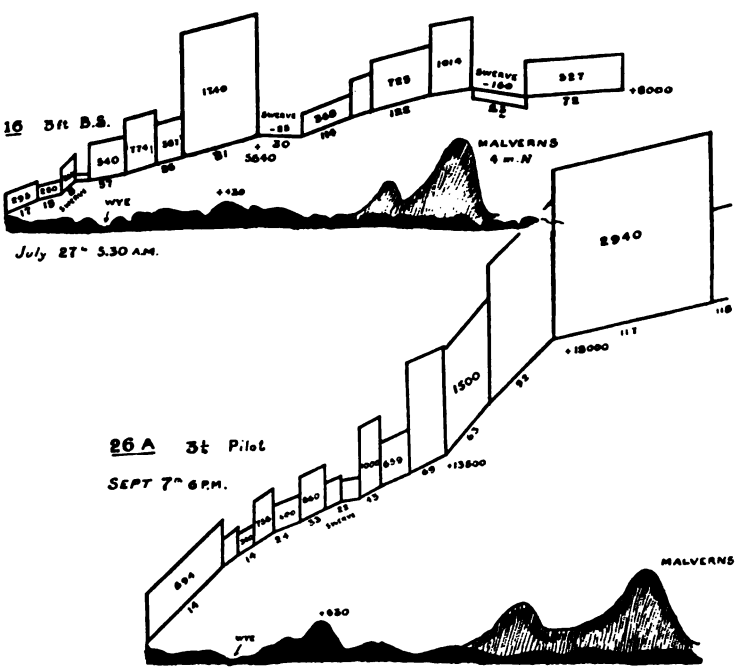

FIG. 8.

Easterly Winds.—(i.) The balloons 29-31A were sent up in anticyclonic conditions in September with very light airs at the earth's surface. The apparent effect of the bend in the Wye and the Harewood watershed is to form a region in the atmosphere extending to great altitude, which may, as regards the motion of a particle, be compared to a deep basin whose high rim lies over the watershed. As will be seen the balloons usually take to the bottom of this basin over the Wye at first, and under the influence of the local breeze and their lifting forces move in a spiral upwards approaching the rim, around which they speed with increasing velocities until attaining a sufficient velocity or meeting a sufficient upper current to carry them out of the area (Fig. 9).

(ii.) No. 13 was sent up in semicyclonic conditions on July 24. There was a very sluggish South-east air moving up the Wye basin. The balloon makes several apparent attempts to escape from the "air-basin," by moving to either side of it with increasing velocities over spurs of the ground below. It appears to fall suddenly back over its course after two such attempts with a collapse in vertical velocity at bottom, finally running up the Hoarwithy stream towards the high "air-mountain" over the Aconbury Hill with increasing velocity until disappearing in stratus at 9000 ft. (Fig. 9).

(iii.) Nos. 35 and 38 were sent up in cyclonic weather. No. 38 follows the Wye Valley and Hoarwithy stream with high vertical velocity and decreasing horizontal velocity. The lowest velocity occurs over the lower part of the stream. Unfortunately the balloon burst when reaching the higher slopes of the basin over Little Dewchurch at a height of 9000 ft. A shallow depression was moving South-east over Cornwall

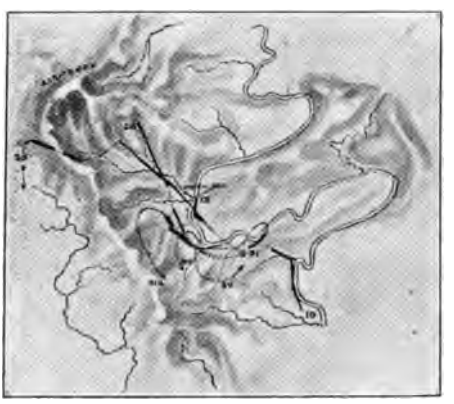

FIG. 9.

with heavy rain in its front portion. It returned over its track two days later, causing squally weather. The wind appears to be gradually decreasing in the upper layers, and probably changes similarly to 35 at the top of the ridge.

No. 35 is especially remarkable in view of the general cyclonic movement, and because its instrument record is instructive (see Figs. 9, 10).

The movement through the "air-basin" to the top of the rim is very slow and laborious, the balloon keeping to the valleys as long as possible, and changing direction when necessary with low vertical velocity (as in the case of 16). The rises and falls of ground are in general faithfully reflected by the vertical velocities, and the instrument record corresponds.

Directly the top is passed at an elevation of 19,000 ft., a slow Northerly air is met with blowing along the main ridge to the south. A depression at the time was over the Scilly Islands moving south. A light air at this elevation was therefore moving along the ridge towards the centre of the depression. The balloon, however, was picked

up at Monmouth, 12 miles south of this place, and the instrument recorded a height of 59,000 ft. The remarkable fact therefore appears that there was practically no Easterly upper current on this occasion up to an enormous altitude, and that a very sluggish movement of the whole upper atmosphere was taking place to the South in the wake of the depression.

The Aconbury watershed clearly marks the general change of wind at an altitude of 19,000 ft., and we may consider this altitude to be near the top of a great "air-mountain" formed in these conditions by this 900 ft. hill.

Measurement of Effects.—An attempt was made to discover some relationship between the increment of vertical velocity over a hill and other factors such as the horizontal velocity of the wind and the height of the balloon above the hill.

Such a relationship, if it exists, is evidently a most complex one; moreover, a difficulty is met with at the start in the absence of a constant velocity to which variations could be referred. In the formula on page 31, the hydrogen velocity depends on the value of the assumed constant μ, which can only be determined approximately from the average of a large number of observations.

It seemed best in any individual case to refer variations to the average velocity over the run, provided the latter was sufficiently long. This, however, limits the investigation, and introduces the larger errors accompanying long ranges.

The averages were therefore worked out in all cases and substituted in the above formula, where the approximate lifting force L was known. The result showed large variations in the value of μ, but this perhaps was in part due to inaccuracy caused by determining L from the volume.

The variations in L were also examined as following from observed variations of velocity from the mean, but the cases in which an original value for L was accurately known were too few to give any definite results.

Moreover, owing to the low conductivity of the rubber it appeared from experiment probable that the relative density ρ is by no means constant, fluctuations in temperature of the air being communicated to the hydrogen, but relatively slowly.

The velocity variations of six balloons passing on different days over the same locality, viz. the Valley of the Wye and How Caple ridge, were however compared, with the following approximate results:—

1907.	No.	Size.	Period of time.	Rise in ground.	Balloon heights.	Increases. Percentage to V. V.	Percentage to H. V.
			Min.	Ft.	Ft.		
Sept. 4 . .	20	2 ft.	2·1	300	7500-10,500	162	65
,, 6 . .	26	1 m.	3·4	400	6250- 8500	56	109
,, 7 . .	26A	,,	4·2	500	7000- 9000	106	120
Oct. 2 . .	34	¾ m.	1·4	400	4800- 5500	89	112
,, 13 . .	39	,,	1·8	400	7000- 8000	240	107
,, 15 . .	40	,,	3·3	400	7000-11,000	350	250

No. 40 is a balloon in which the average is spread out over a greater distance than in the other cases. But it is also one sent up in more definite and deeper cyclonic conditions.

An average increase, then, in horizontal velocity of South-west wind over How Caple ridge at this bend may be roughly set down at about 100 per cent normal conditions.

The average increase in vertical velocity is evidently a very variable quantity depending on many conditions; and a much larger number of observations must be taken to discover any relation between these.

Comparison of Velocities with Temperature Gradients.—The general rule in the atmosphere appears to be that the steeper the temperature gradient the less velocity of the wind, and *vice versa.* It may, however, be doubtful if this general law applies to any particular or sudden local variation of wind velocity, *i.e.* when the atmosphere is not free. It is of interest, however, to compare the instrument records of temperature with the wind velocities found by the theodolite at various heights in such few cases as were available.

No. 10 balloon differed from others in its temperature gradients owing to cloudy conditions.

The balloons 19, 24, and 35 were, however, sent up on fairly clear evenings.

The velocities of No. 19 in West to North-west wind have already been noted as exceptional.

An examination of the temperature gradient shows that it runs parallel with the velocity variations (see Fig. 6).

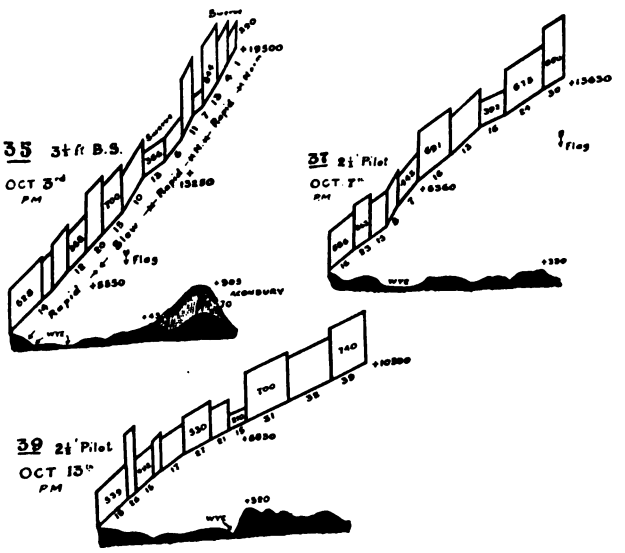

FIG. 10.

The initial decrease of temperature (1500-5000 ft.) is very rapid, with low horizontal velocity and roughly normal—but increasing—vertical velocity. From 5000 to 8000 ft. there is a sudden check in decrease of temperature almost amounting to an inversion; the vertical velocity gives the extraordinary jump already noticed, and the horizontal velocity rises from 12 to 24 miles an hour. From 8000 ft. to about

10,000 ft. the temperature falls rapidly, the vertical velocity almost collapses whilst the horizontal velocity sinks low at first, but increases rapidly at about the 10,000 ft. level.

The balloon now disappears in stratus cloud lying just over the watershed. The temperature gradient, however, is suddenly checked. This check may be due to the cloud, but coincides with the ridge over which high velocities would be expected, moreover the temperature again falls rapidly at a later period corresponding with lower ground and lower velocities beyond.

An examination of Nos. 24 and 35 shows a similar correspondence of temperature and velocity gradients (see Figs. 7, 10).

The case of 35, however, is unusual because the horizontal velocity is throughout the track low. The gradient of track is steep, the vertical velocity nowhere extreme, but varying according to the ground. The temperature gradient thus follows the variations of vertical velocity and the ground.

These isolated cases are, no doubt, insufficient to deduce any conclusion, but they do point to a correspondence of temperature gradient and local velocities. That the temperature should decrease at a less rate the faster the balloon rises seems difficult to account for, unless greater radiation effects or an actual convection current is taking place over the locality where this occurs.

Gradients of Track.—The ratio of vertical velocity to horizontal velocity obviously depends on the slope of the track, *i.e.* $\tan B = \frac{V.V.}{H.V.}$ where B is the angle of slope.

Now, it appears that a maximum value for B usually occurs at some distance from a hill on its windward side, and this is noticeable in the exceptions as well as in the rule. The maximum is followed by a minimum over or just before the high up slopes of the hill, whilst over the top and just beyond, the slope again increases. The vertical velocity and horizontal velocity vary respectively in direct and inverse proportion, the maximum value for both velocities occurring at the outflow over the hill. The balloon, in fact, takes a jump up at some preceding point, often a lower ridge, rising sufficiently apparently to cross the valley area. This preliminary rise at lower elevation is sometimes carried out with a slow spiral motion.

It then performs a slow swoop with downward tendency over the valley till near the steep slope of the hill, when it rushes up and out over the top with upward tendency at first and greatly increased velocities.

Variations of Pressure.—The law suggested for the free atmosphere by Clayton and Egnell ($Vd = \text{constant}$) does not strictly apply to sudden local variations.

In these cases, as is well known in the case of cyclones and anticyclones, the velocity of the wind depends largely on the barometric gradient, *i.e.* on the relative rate of increase or decrease of the pressure.

If, therefore, it is true that a hill increases the velocity of wind blowing over it and a valley decreases this velocity, it seems possible that a valley increases the pressure and a hill decreases it throughout the strata in which the effect was observed. The isobaric surfaces would be raised

over the valley and depressed over the hill, in section appearing as inverted basins and hills respectively, whilst in plan following the features of the ground. The terms "air-basin," "air-mountain," etc., could only therefore be used with this significance. It also appears that the actual fluctuation in the pressure might be minute, yet as it occurred in a short relative space the barometric gradient would be suddenly and sharply affected, causing sudden accelerations to total velocity and to both vertical and horizontal components.

Horizontal deflection of a current moving rapidly across these localities, under independent general forces, might not be great except under favourable conditions. The tendency of motion laterally along the isobars might be replaced by a motion vertically, as appears the case near the centre of a cyclone.

Water Analogy.—The atmosphere does not present a case strictly analogous to a stream of water, because it is a compressible mixture of gases thinning off into space with no known upper surface.

As Mr. Froude points out, in a stream of water passing over a rocky bottom, swirls or eddies are produced at the bottom with vortex motion extending upwards for a certain height in the liquid.

At the surface, if the depth is not too great, an undulation takes place, the level being raised just before the point of a rock, depressed just over it, and raised just beyond.

The differences of pressure are, in fact, transmitted through the body of the liquid to its upper surface, there causing an undulation under the influence of gravity.

May we not suppose, then, that a similar process takes place in a moving body of air passing over valleys and hills, and that a mechanical action due in part to obstruction at the bottom causes variations of pressure which are transmitted through the body of the atmosphere to its distant confines?

And further that, without much horizontal deflection (except near the earth's surface), particles of air moving at great elevation in a general current over these disturbances, affected also by differing radiation effects or actual convection currents over the hills, would be accelerated and retarded with large upward or downward components of motion.

Is it not also possible that an area is often formed, say by a superimposed current, presenting something analagous to a surface in the case of water, where condensation takes place in a cloud form presenting in visible shape the reflections of hill and valley disturbances many thousands of feet below?

If these observations are in the main correct, the suspicion is justified that the vertical velocity of a balloon travelling upwards through the lower and middle atmosphere is by no means a uniform one, and it appears that there are sudden fluctuations in both vertical and horizontal velocities of wind which, though variable in different conditions, are mainly of a permanent nature, due to the shape of the earth's surface.

The measurement of these effects can be carried out by balloons and special theodolites, and a topography of the air made in any locality, which, studied in conjunction with the records of the instruments carried

and with relation to general atmospheric conditions, presents a field of research of fascinating interest and of great possibilities.

NOTE.

Explanation of Diagrams.—The following scales apply to the printed diagrams :—

Horizontal scale for Plans	4 miles	= 1 inch.
,, ,, ,, Sections	5 ,,	= 1 ,,
Scale for Ground Heights . . .	about 0·4 ,,	= 1 ,,
,, ,, Balloon ,, ...	2 ,,	= 1 ,,
,, ,, Vertical Velocities	about ½ m. per min.	= 1 ,,

The vertical velocities are written in the parallelograms over the balloon tracks, and are in feet per minute. The horizontal velocities are written underneath the balloon tracks, and are in miles per hour. The temperature gradients, where an instrument was carried, appear under the horizontal velocities.

ADDENDUM.

A further test as to the accuracy of the method for range-finding has more recently been applied. On January 11, 1908, a mark consisting of an upright board tapered at the ends, 3¼ feet high and 10 inches broad, was erected on the top of one of the Welsh hills to the south-east of Bangor. On the 12th, Professor Orton and I each took 5 momentary readings of the angle subtended by this board at an observing point at Bangor, without recalibration of the cross-threads. The cross-threads were then cleaned and recalibrated, the new values of the constants differing by 4 seconds from the original ones. On the 13th I repeated the observations.

The horizontal ranges were then calculated from the mean of each series and from the observed altitude, and compared with the actual range as measured accurately on a 1-inch Ordnance Map.

The following tabular statement shows the results :—

January 12.	*Orton.*	*Ley.*	*January* 13.	*Ley.*
	22 secs.	20½ secs.		20½ secs.
	21½ ,,	21 ,,		21½ ,,
	21½ ,,	21 ,,		21 ,,
	21½ ,,	20½ ,,		21 ,,
	22 ,,	20½ ,,		21 ,,
Average . (Elevation + 3° 59′)	21·8 ,,	20·7 ,,		21 ,,
Calculated Range	5·80 miles	6·11 miles		6·03 miles
Map ,,	6·18 ,,			
Error per cent	6·1	1·1		2·4

The observation of a narrow rectangular object is more difficult than that of a circular area ; moreover, the difficulties caused by shimmer due to varying refraction at such a low angle of elevation are greater than those occurring at normal balloon altitudes.

DISCUSSION.

Mr. C. J. P. CAVE remarked that he was somewhat disconcerted at the results of Captain Ley's observations. He himself had made a large number of observations of pilot balloons by the one theodolite method, assuming the rate of ascent to remain constant; Captain Ley's observations seemed to show that the rate of ascent was far from uniform. But if there is an upward current over a hill there must be a downward current beyond it, and the one theodolite method probably gives a fair idea of the direction and velocity of the wind if average values are taken, though any single observation might be unreliable. One may frequently see the effect of an upward current over a hill in the cloud capping it; he had seen a good example in the Isle of Wight, where the cloud formed an outline of the hill, and extended to about three times the height of the hill. From some of the records of the International Commission of Scientific Aeronautics, it would seem that when a balloon gets into a warmer stratum its ascensional velocity diminishes, which is contrary to Captain Ley's observations.

Mr. W. W. BRYANT said that he had been much interested in Captain Ley's paper, but to one in the habit of using a micrometer for measuring small objects it is not easy to admit the advantages of the suggested arrangement in place of a micrometer. Fitting in the balloon in the intermediate sections seems open to considerable uncertainty, though at the intersections it would be easier. With practice, however, he thought one could get fairly good results, and, as Captain Ley said, this is the best form of several he has tried. He (Mr. Bryant) was prepared to admit that he ought to know best about this particular form of observation. One or two other points he would mention. As the density of the air decreases with the height, one would expect the effect of a range of hills on the successive "level" surfaces upwards in the air to be considerably exaggerated, so that an effect at a height many times greater than that of the hill seems quite reasonable. The fact that it is not exactly an ascending current, but a bend in the stratum, so to speak, would lead one in such a case to accept as quite natural the slow decrease in temperature with greater ascensional velocity which Captain Ley seems to find. On this, however, he (Mr. Bryant) could not claim to speak with any authority, so perhaps somebody would correct him. As he was allowed to see the large map on which the tracks were laid down, and as he was born in sight of the Malvern Hills, May Hill being also a familiar landmark of the neighbourhood, he was particularly interested to notice that one of the largest tracks (No. 22) ended just over his native village.

Capt. A. CARPENTER, R.N., wished to confirm the remarks as to the effect of an uneven bottom to a stream causing disturbances at the surface. It was well known to navigators that where there was a strong current in a confined channel overfalls occurred at the surface above obstacles that might be as much as 15 or more fathoms deep.

Dr. W. N. SHAW remarked that, so far as he knew, there was no precedent with which to compare Captain Ley's results. This circumstance, while adding to the interest of the paper, also added to the difficulty of grasping the precise meaning of the results. He thought there had been a little temptation to jump to the conclusion that the increase of the velocity over a hill must be due to vertical velocity in the atmosphere caused by the hill. In flowing water there certainly was a variation in the surface motion when a deep current ran over an obstacle, but the vertical velocity of the balloon was due, in the first place, to the difference of density of the balloon and surrounding air, and it was too soon to say definitely that the acceleration of the balloon in the atmosphere represented the effect of the hill upon the motion of the air, and to put all the observed difference upon the vertical velocity of the air without inquiring into

changes of density. The conclusion would be more nearly justified if the temperature gradient was found to increase when the vertical velocity increased, and not to diminish. When no cloud is formed, air with an upward motion is cooling at 1° C. per 100 metres. This is the maximum rate of decrease in temperature, and the balloon carried upward by a rising current without cloud ought to show it. A balloon in the upper regions might be expected to show less temperature gradient if the air was not rising. To a certain extent the absence of this contrast is evidence to the contrary of the suggestion that the effects noticed are due to the vertical movement given to the atmosphere by the obstacles of the surface. He would be glad if Captain Ley would continue these observations, testing them by repetition under different circumstances.

Another point to be noted was, that the method itself must be a great strain upon the observing capacity. A telescope is incapable of producing a point as an image of a point, if the distance of the object exceeds that corresponding to the resolving power of the telescope. The condition that the telescope should produce an image is, that the angle which the object subtends at the centre of the object glass is not less than that which the wave length of light subtends at the distance of the aperture of the object glass. Beyond that distance diffraction begins to interfere with the formation of a true image. With a metre balloon at a distance of 10 kilometres you have got an angle of $\frac{1}{10000}$ part of a radian about the same angle as the wave length of sodium light subtends at a distance of 2 inches. This is close up to the limit of observation with the telescope of a theodolite, and it was therefore desirable to verify the accuracy of the method. One easy way of testing was to observe the apparent size of a sixpence at 200 metres. This subtends the same angle as a metre balloon at 10 kilometres. They could thus find to what degree of accuracy they could measure a distance by Captain Ley's method. The measurements could also be tested by observations with two theodolites. He felt justified in asking Captain Ley for some such elaboration in order to give them the degree of accuracy of the measurements somewhat more in detail.

Mr. W. MARRIOTT said he had been much interested in Captain Ley's paper. His observations seemed to throw considerable light on the formation of clouds. A cloud would sometimes be formed without any apparent cause, but would probably be the result of an upward current induced by the configuration of the ground. Possibly the President could tell them what the rainfall was in the neighbourhood of hills. After referring to the heavy rainfall at Seathwaite, Mr. Marriott showed some lantern slides to illustrate the influence of hills on clouds. He also referred to some special forms of clouds, as the helm bar in the neighbourhood to Crossfell, Cumberland, and the cloud sometimes formed over the Lion's rump at Cape Town. When staying at Malvern one day last summer, he had watched the clouds coming over the Malvern Hills; they seemed to come round, then almost to disappear, and subsequently to re-form. Probably this was due to the phenomenon explained by Captain Ley.

Mr. E. S. BRUCE remarked that he considered it important to both the sciences of meteorology and aeronautics, to map out in this way all the various currents and disturbances of the air. These observations would be of the most extreme importance, preliminary to aeroplane voyages, as pointing out the dangerous places. In the case of uprushes of air over hilly districts a balloon would not be seriously affected where an aeroplane would probably be upset.

The PRESIDENT (Dr. H. R. MILL) said that the action of air passing over a hill in producing an increase in the amount of rainfall hardly led him to the same conclusion as that arrived at by Mr. Marriott. If these tremendous uplifts really occurred, the cause would be much too great for the comparatively moderate effect, as far as rainfall was concerned. He would like to see experiments tried in some place where there was a very much greater elevation

of the earth's crust than near Hereford. The valley of the Eden would be most suitable, as the escarpment of the Crossfell range was the most continuous and highest mountain wall in England, and rising as it did east of the plain, the position was eminently adapted for such observations, as a balloon sent up on the western margin of the Eden valley would almost certainly drift over the Crossfell range. Meanwhile suspending judgment on the matter, he would invite Captain Ley to reply to the remarks which had been made.

Capt. C. H. Ley, in reply, said that Mr. Bryant had suggested using other forms of micrometer. He had, however, after experience come to the conclusion that one would require three hands to use any usual form of micrometer whilst keeping the balloon in the required position in the field of the telescope.

With regard to Dr. Shaw's remarks he had not meant to assert that a check in temperature gradient was necessarily due to an ascending current of warm air, but rather to suggest this explanation as a possible one in certain cases. He thought that it was too early to come to a conclusion on this point. Regarding the optical question it might be perfectly true that a 2-inch object glass could not resolve two points of light less than $2\frac{1}{4}$ seconds apart. To distinguish between a circular area of 20 seconds in diameter and one of $22\frac{1}{4}$ seconds diameter with such an aperture was, however, he suggested, an entirely different proposition. From experience he felt certain that the difference between a 20-second area and a 21-second area could be fairly easily made out. To take a parallel illustration, it was much harder for the eye to distinguish clearly the edge of the narrow part of a church steeple near its high point, than to appreciate the edge lower down where there was a broader mass of the building.

With reference to Dr. Shaw's desire for further details of the tests applied, the figures for the Flag Tests are, with the detailed tables, now in the Society's office. Tests as to ranges of distant fixed objects of known size were made in September, but this was before any idea of plotting the tracks was entertained, and no record was kept. Moreover, the objects were of a comparatively large size, subtending angles of one minute or more, and great comparative accuracy was therefore obtained. The constant values for the cross-threads were obtained by measurements of known black circles at a known distance, so frequently carried out with the same instrument by him and others that the personal errors were thoroughly known, and the doubt, that there would not be relative accuracy in one set of observations by the same person on fixed objects in clear conditions, was never entertained.

"Dust Devil."

In the Report of the Surveyor-General of Ceylon for 1905 there is an account of an unusually good specimen of what is popularly known in the East as a "dust devil," which was observed by Mr. J. B. M. Ridout of the Survey Department, Colombo. His description is as follows:—"It was about 12.30 p.m., and I was at the corner of this block opposite the Fort station when I first saw it. It was then to the north side of Norris Road, just on the Fort side of the Racquet Court, the appearance it presented being a rough vertical column of dust about 30 ft. high, perhaps 4 ft. in diameter at the top and where it touched the ground, and 8 ft. at a height of 3 ft. from the ground. It was revolving rapidly in the reverse direction to the hands of a clock when looked at from above. It lasted about three minutes, and moved along the road in the direction of the Fort, finishing in the corner at the north-east end of the Fort station, where the posts carrying the telephone wires are. It was then about 40 ft. high, being, except just at the bottom, in the form of a column about 2 ft. in

diameter with perfectly smooth sides, and at the top the dust was rising just like the smoke from a chimney. It was still perfectly vertical except the top 10 ft. or so, which were inclined to the south. At the bottom it bulged out, being about 3 ft. in diameter where it touched the ground, and 4 or 5 ft. at 3 ft. higher; in fact, the whole column was in shape very much like the glass of an enormous thermometer. At the end of the Fort station it disappeared. Whether the currents of air were broken by the roof of the station, the tree and the telephone posts, or whether it faded away because there was no dust on the railway line for it to pick up, I do not know; but I am inclined to think that the former is more probable, as I went at once on to the railway platform, but was unable to detect any disturbance either on the permanent way or on the surface of the lake. I should have gone to see what sort of a track had been left on the road, but could not as my train was due.

"The wind at the time was practically *nil*, what little there was being North-east."

Penalty for Counterfeiting Forecasts.

The Agricultural Appropriation Bill for the fiscal year ending June 30, 1906, (*Statutes at Large*, vol. xxxiii. part 1), contained the following legislative item:—

Any person who shall knowingly issue or publish any counterfeit weather forecast or warnings of weather conditions, falsely representing such forecasts or warnings to have been issued or published by the Weather Bureau, or other branch of the Government service, or shall molest or interfere with any weather or storm flag or weather map or bulletin displayed or issued by the United States Weather Bureau, shall be deemed guilty of a misdemeanor, and on conviction thereof, for each offence, be fined in a sum not exceeding five hundred dollars, or be imprisoned not to exceed ninety days, or be both fined and imprisoned, in the discretion of the court. (See Act of Congress approved March 3, 1905.)—*U.S. Monthly Weather Review*, June 1907.

Memorial of a Wet Summer.

The Rev. Frederick Ackerley gives, in a recent number of *Notes and Queries*, an account of an upright stone pillar which was erected (by a person of the name of Harrison) some twenty-five years ago to commemorate a very wet period. It stands in a field adjoining Brows Farm in Grindleton (in the West Riding of Yorkshire), and was put up as a memorial of a wet summer, when the rain fell every day for thirteen weeks in succession.

The Greatest Height reached by a Ballon-Sonde.

A balloon sent up by the Meteorological service of Belgium, on September 5, 1907, holds the record for greatest height. This balloon, starting from the Uccle Observatory at 6.58.30, reached a height of 85,270 ft., or 16 miles, at 7.53.31. The barometric pressure at this point was only 0·67 inch.

Previous to this the more memorable ascents were:—

1906, May 3, at Strassburg . . .	79,400 feet
„ June 7, at Milan	78,085 „
„ November 8, at Paris . . .	78,380 „

A balloon sent up by the Meteorological Service of Belgium on July 24, 1907, reached a height of 69,350 ft.

In the *Annuaire Météorologique* for 1907 there will be found an interesting article by M. J. Vincent on "The Ascents of Ballons-sondes in Belgium" (with figures and maps).

INDICATIONS OF APPROACHING FROST.

By RICHARD STRACHAN, F.R.Met.Soc.

[Read December 18, 1907.]

The *Quarterly Journal of the Royal Meteorological Society* for April 1906 may be cited as showing the connection of meteorology with the affairs of everyday life. Mr. F. Druce has said that "the people of this country should wake up and get some means of foretelling destructive frost"; and two past Presidents of the Royal Meteorological Society have remarked, Mr. E. Mawley "that our fruit-crops are greatly at the mercy of late spring frosts," and Mr. R. Bentley "that it would be of immense value if accurate forecasts of frosts in the spring months could be established in this country."

There can be no doubt of the importance to horticulturists, and agriculturists generally, of being able to foresee the coming on of frost or hoarfrost. Every one recognises this when consideration is given to the havoc wrought by frost on unprotected crops and plants. Frosts in spring, even in June and occasionally in July, in England cause much loss or depreciation of fruits and plants. Mr. J. Glaisher, in Hughes's *Fourth Reading Book*, 1855, wrote: "In calm and clear nights a terrestrial radiation thermometer may read less than 32° in every night of the year"; and added: "The greater coldness of grass than that of air in clear and calm weather, in places sheltered from the sun but open to a considerable portion of the sky, may continue all day as well as all night." Mr. R. H. Scott, in his *Elementary Meteorology*, states: "A knowledge of the dewpoint in the evening enables them [gardeners and others] to form a fair estimate of the probable minimum temperature on the grass during the night. If the dewpoint be found to be above 32° they need not fear that hoarfrost will occur; but if it be below 32° it is advisable to cover up delicate plants for fear of their being nipped if the sky should clear before sunrise." This hardly goes far enough, for a thermometer on grass may fall many degrees below a dewpoint which is much above 32°; just what happens in the warm months occasionally.

That this teaching is not sufficient the following instances will render evident. They are from the *Greenwich Observations* for the year 1902. The daily means for the dewpoint occur in the early morning and evening, so that they may here be taken for evening observations; and the minimum temperature on grass during the night is taken the following morning, with the state of the sky in the interval, as follows:—

		Dewpoint.	Grass.
January	4	45°7	29°0, bc
	5	36·4	29·0, „
	12	43·2	27·2, „
	13	32·8	18·5, hoarfrost, cb
	17	40·3	20·4, slight fog
	23	44·5	29·5, bc
	24	37·9	25·2, hoarfrost, mist
	27	38·1	27·5, bc, r
	28	36·7	22·5, hoarfrost, b
July	11	44·5	30·8, heavy dew, b

These dewpoints being above 32° do not indicate proximate frost

unless the sky becomes clear during the night; if the sky continues overcast there will be no frost the next morning; but the grass temperatures all show that there must have been frost during some portion of the night. On June 8, 1906, the mean temperature was 55°·4, next morning the grass was 29°, the sky having been very clear during the night.

Accumulating facts, co-ordinating them, and drawing inferences is the inductive method of science. What has been said is borne out by a study based on the observations of the entire year 1902:—

1902.	Mean Temperature. Air at 9 p.m.	Wet-bulb at 9 p.m.	On Grass.
	°	°	°
January	41·6	39·9	31·1
February	35·1	33·8	25·1
March	44·1	41·9	31·1
April	45·8	42·7	28·8
May	47·7	45·6	33·0
June	55·9	53·2	41·0
July	59·4	55·2	43·4
August	57·9	55·6	44·7
September	53·9	52·0	39·7
October	48·7	46·9	37·1
November	43·7	42·5	33·0
December	40·8	39·0	33·1

The dewpoint may be easily inferred from the depression of the wet-bulb; and it will be seen that the grass was colder than the dewpoint in every month. However, this exposition does not assist prevision of frost. Investigating the subject from a daily point of view may be more hopeful. This may be set forth as follows, under the same headings, with addition of weather notations for the interval of night:—

	Air at 9 p.m.	Wet-bulb at 9 p.m.	On Grass.
	°	°	°
April 30	50·1	45·1	29·0, op
May 1	40·6	39·2	27·0, cp
3	45·4	44·1	27·4. bc
4	...	...	25·4, dew, bc
5	39·9	38·3	23·0, hoarfrost, bc
6	40·1	38·4	25·2, cb
7	41·0	40·6	24·8, o
8	42·2	40·2	27·1, hoarfrost, b
9	42·0	40·2	24·8, ,, bc
10	40·1	39·3	24·9, bc
11	...	...	27·0, dew, o
12	43·0	40·3	24·0, hoarfrost, b
13	39·7	37·4	22·6, ,, bf
14	39·2	38·8	25·3, ,, bc
June 9	46·9	44·4	29·8, heavy dew, b
July 11	51·4	49·0	30·8, ,, ,, b
Sept. 18	42·7	42·0	29·4, hoarfrost, b
19	48·0	46·0	29·3, dew, b
24	48·3	47·2	30·5, heavy dew, b
25	48·3	48·0	30·1, ,, ,, b
26	49·3	48·9	31·9, dew, b
Oct. 1	51·3	49·0	30·7, op
7	48·4	47·6	30·4, bc
18	46·3	44·8	27·8, bc
22	49·8	46·5	31·2, dew, bc
28	51·1	50·0	29·6, ,, b
30	47·1	43·6	29·2, hoarfrost, b

In May the grass was colder than 32° on 15 days. The psychrometer at 9 p.m. on the preceding days gave no indication of such cold,

but the evenings or nights were clear and may have led to anticipation of frost on the ground the next morning. June had frost in the morning of the 10th, accounted for by clear sky after midnight. July had frost in the morning of the 12th, accounted for by clear sky all night. August had no frost. September had frosts on 5 days, no wet-bulb or dewpoint indication of them, but the sky was cloudless for all these nights. October had frosts on 6 days, and the same remark applies, except for the night of the 1st, which was overcast. There is no need to discuss the other months in this manner, for frosts are frequent in them, and expected. January, for instance, had frosts on 18 days, February 15, March 19, April 21, November 11, December 15. In all these cases the grass was colder than the air at 4 ft., colder even than the dewpoint, frequently very much colder. Indeed, it will be found by comparing the mean monthly air temperatures with their corresponding wet-bulb temperatures, or their dewpoint values, with means of the grass temperatures, that the latter are almost always the least.

In the majority of cases the evening dewpoint is no indication of frost unless the sky during the night becomes clear, or a radiation fog is on the ground with a clear sky above it. The grass may be below 32° without dew being observed, perhaps because too slight, or it may have been obliterated by rain or dissipated by rise of temperature. Nevertheless not every night having a clear sky will be attended by a temperature on the grass sufficiently low to produce frost. Forecasts, therefore, may frequently fail, but it is better that they should sometimes do so than that we should suffer from an unexpected frost against the destructive effects of which precautions had not been taken. Better to be wrong with this problem than right; but if you are right and have taken due precautions you have your reward.

The problem cannot be adequately expounded by the averages published for meteorology. For the purpose of making forecasts the psychrometer should be noted at or after sunset, or at 9 p.m., and the amount of cloud at the time, and during the forepart of the night if convenient. The dewpoint can then be found by Glaisher's *Hygrometrical Tables*, or roughly by taking the difference between the two thermometers from the reading of the wet-bulb. When the dewpoint is at or below 32°, frost is in evidence, but may be evanescent, due to a rise of temperature, with change of wind, rain, or overcast sky. Even when it is above 32°, if the sky is clear it is probable that the temperature on the ground will go low enough for frost to form. Thus the evening observations should lead to a good guess of what may happen during the night; presumably if the sky is very clear, however hot the weather, there may be hoar frost or dew the next morning, so that precautions should be taken.

Addendum.

Mr. Strachan explained on the blackboard the general problem by the following empirical scheme:—

Air, 9 p.m.	Stars Visible.			
	All.	Many.	Few.	None.
°	°	°	°	°
60 . . .	30	40	50	60
50 . . .	25	33	42	50
40 . . .	20	27	33	40
30 . . .	15	20	25	30

The air being 60°, and brilliant starshine, the indication is for something greater than 30° on the grass, and there is no fear of frost for temperature above 60°; if 50°, nothing less than 25° need be expected, but then there is a probability of frost with bright starshine; and the probability increases at 40°, for frost may occur even with partial starshine; while for 30°, frost is in evidence for all states of the sky. For no starshine the sky must be overcast, and, if the weather is rainy or damp, the grass may remain, as well as the air, at the same temperature during the interval, unless there is an atmospheric change of temperature, then the minimum at 4 ft. and that on the grass will be alike.

Scintillation and Rippling of Distant Lights.

I was at Brighton on Sunday, November 3, 1907. The weather was dull in the morning, and some rain fell between 1 and 2.30 p.m. The clouds cleared a little in the south-west about 3 p.m., and the sun then came out for some time. This was followed by a brilliant sunset, the clouds being tinged with beautiful colours. Soon after 5 p.m. I saw the electric lights at Worthing. As it grew darker these became brighter. I then noticed that the lights scintillated or twinkled very much like stars. There was also the appearance of rippling or waves along the row of electric lights. I do not remember to have noticed any similar appearance of the twinkling and rippling of the lights anywhere else.

Worthing is twelve miles west of Brighton, and, owing to a slight bend in the coast-line, it is seen over the sea. The wind was from the South, and was only light in force. It is probable that there were inequalities in the velocity of the wind over the twelve miles of sea, and so these may account for the scintillation of the lights and also for the rippling, which was apparently from south to north.—WILLIAM MARRIOTT.

International Meteorological Committee.

A meeting of the International Meteorological Committee was held at Paris on September 10, 1907, and following days. At the close of the session M. Mascart resigned the office of President, and Dr. W. N. Shaw, Director of the Meteorological Office, London, was elected President. Dr. G. Hellmann, Director of the Prussian Meteorological Institute, was elected Secretary in the place of Prof. Hildebrandsson, who retired upon his withdrawal from the post of Director of the Swedish Meteorological Office. M. Angot (Paris), Dr. H. E. Hamberg (Sweden), Dr. Maurer (Switzerland), and Mr. R. F. Stupart (Canada) were elected to fill the vacancies on the Committee.

PROCEEDINGS AT THE MEETINGS OF THE SOCIETY.

November 20, 1907.

Ordinary Meeting.

HUGH ROBERT MILL, D.Sc., President, in the Chair.

WILLIAM SMITH ALLELY, 39 St. Oswald's Road, Birmingham ;
HARI GOPAL BANERJI, M.A., Khatmandu, Nepal, India ;
Capt. E. HAMILTON BATE, H.M.S. *Hannibal*, Devonport ;
R. JOHNSON CLARKE, F.S.A., Monrovia, Liberia, W.C.A. ;
ARTHUR DALLAS, 4 Peking Road, Delhi, India ;
CHARLES NEVILE DAY, Easton, Stamford, Northants ;
JOHN DESMOND, R.V.S., G.M.V.C., Adelaide, South Australia ;
Capt. JOHN ELMES, Anchorage, Clifton Avenue, West Hartlepool ;
Capt. HUGH FINDLAY, 36 Gracechurch Street, E.C. ;
WILLIAM GAW, 88 Avenida Espana, Santiago, Chile ;
HEMCHANDRA GORSAIN, Tezpur, Assam, India ;
Capt. GEORGE GREGORY, 18 Leadenhall Street, E.C. ;
Capt. HUGH HOLLIES, Castle Rising, Norfolk ;
HENRY J. HUNT, The Priory, Wimbledon Common ;
Capt. EDWARD GATES JAMES, Fradswell, Stafford ;
ARTHUR LANDER, 17 High Street, Canterbury ;
Capt. WINDEYER GEORGE LINGHAM, 67 Woodland Rise, Muswell Hill, N. ;
Capt. ARTHUR WILLSON M'KELLAR, 138 Leadenhall Street, E.C. ;
EVELYN NEVILLE PLEVINS, Woodford House, near Thrapston, Northants ;
Capt. SIDNEY PLUNKETT, West Hill House, Milton, Gravesend ;
THOMAS RULE, Kaombi, Chiromo, B.C.A. ;
Capt. ROBERT WILLIAM SCARFF, Tilbury Dock ;
Capt. W. SOPWITH SHELFORD, 80 York Mansions, Battersea Park, S.E. ;
EDMUND J. WALSH, 402 O'Connor Street, Ottawa, Canada ; and
Capt. ROBERT CAMPBELL WARDEN, 79 Mark Lane, E.C.,
were balloted for and elected Fellows of the Society.

THE PRESIDENT said : During the recess since the last Meeting of the Society in June its work has not been intermitted, and, apart from the usual routine, there are several points of interest which I think might be brought before the Fellows, however briefly, in commencing a new Session.

The Society was represented by an attractive exhibit at the Lincoln Show of the Royal Agricultural Society in the last week of June, and the opportunity was taken advantage of by a great many farmers and others attending the Show who had not previously seen a climatological station at work. Mr. Marriott gave several discourses on that occasion which aroused general interest ; and he has also continued the lectures to Local Scientific Societies from which such excellent results were obtained last year.

The efforts of the Society to advance the study of Meteorology in Schools and Colleges have not been relaxed, and a good deal of information on the subject has been acquired since our last meeting, the results of which will be presented to you before long. It has been decided to invite a competition amongst elementary School Teachers and others for the best specimen lesson on the Study of the Weather adapted for use in Schools ; but the most scrupulous Fellow need not fear that the Society is entering into rivalry with the " Limerick " press.

The Joint Kite Committee, in which the Society is associated with other

bodies, has been extremely active, and has secured several series of ascents in connection with the International Co-operation in July and September last, some of the results of which will be placed before the Society this evening. The study of the Upper Air promises to be the most important contribution of the early part of the twentieth century to the science of Meteorology, and it is appropriate that the Symons Memorial Gold Medal of the Society for next year should have been awarded by the Council to M. L. Teisserenc de Bort, whose untiring efforts have been largely instrumental in leading to the splendid results now being obtained. It is gratifying to be able to announce that M. Teisserenc de Bort hopes to attend personally at the Annual Meeting in January to receive the Medal, and I am sure that he will be very heartily received.

It has been my privilege to represent the Society officially at the celebration of the Centenary of the Geological Society in September last, and to convey the congratulations of the students of weather to Sir Archibald Geikie, the master of weathering. I have also represented the Society on the Science Committee of the Franco-British Exhibition, and, together with several other Fellows of the Society, on the sub-committee which is organising the meteorological part of that important undertaking. Dr. Shaw, as Convener of the Sub-Committee on Meteorology, is carrying out the general arrangements, and we shall have the invaluable assistance of Mr. Marriott in arranging the details.

Some important changes have occurred in the Meteorological organisations of the Empire, chief amongst which I may mention the formation of a Federal Meteorological Department in Australia, and the revival of the Colonial Meteorological service in Jamaica under the charge of our colleague Mr. Maxwell Hall. It is pleasant to find that, after having been cared for Meteorologically for some years by the United States Weather Bureau, the leading West Indian Colony has resumed observational work on its own authority.

The succession of our old friend, Dr. Hellmann, to the Professorship of Meteorology in the University of Berlin and to the Directorship of the Prussian Meteorological Institute was only to be expected ; but we congratulate him none the less heartily upon the appointment.

The International Meteorological Committee, which has done so much in the past in promoting uniformity in the observations of different countries, has lost the services of its old President, M. Mascart, and its old Secretary, Prof. Hildebrandsson ; but we may feel a certain pride as a Society in the appointment of a member of our own Council, Dr. Shaw, to the Presidency of the International Committee ; and in the appointment of Dr. Hellmann as Secretary we have a further guarantee that the efficiency of the Committee will be in no way impaired by the change.

Dr. Shaw is continuing at the Meteorological Office those interesting conferences on important published meteorological papers which we have all learned to appreciate, and he is also delivering a course of lectures at the University of London upon "Meteorological Organisation and Methods." The improvement in the position of Meteorology as a University subject in this country is extremely gratifying ; but I regret to have to record a backward movement in the matter of the recognition of Meteorology at the Meetings of the British Association. It may be that this Society has been too considerate in not impressing upon the British Association the importance of the science and its claim to be represented in a section by itself or grouped with other branches of observational study. The unsatisfactoriness of the position of Meteorology in Section A at the last meeting has been commented on in several quarters, and we hope that some improvement will result in consequence.

I may refer to the prosperous state of the Society numerically, twenty-five names being down for election this evening, and thirty-seven for proposal as Fellows. The latter number is, I understand, the largest on any occasion in

the history of the Society, and it is a personal gratification to myself to know that it contains the names of many rainfall observers who have long carried on valuable if unostentatious observations in that department of our science.

I would urge upon the Fellows the great importance of making an effort to improve the position of the Society still further as regards the number of members. Much of the work of such a Society as this depends upon the possession of an adequate annual income, and we have practically no other source of income than the contributions of Fellows. I believe that many suitable and desirable people are ready to join if they could only be sought out and made acquainted with the aims and advantage of the Society. A large membership has many advantages apart from the financial, and it is my hope that all the Fellows will take an increasing share in the work of the Society, and act zealously together in promoting all its efforts, confident that we are engaged in a branch of Science which is entering on a period of rapid advance.

The following communications were read :—

1. "The Registering Balloon Ascents in England of July 23-27, 1907." By W. H. Dines, F.R.S. (p. 1).

2. "Results of the Balloon Ascents made from Manchester, July 22-28, 1907." By J. E. Petavel, F.R.S., and W. A. Harwood (p. 5).

3. "Balloon Experiments in Dublin, July 22-27, 1907." By Professor W. E. Thrift, M.A. (p. 11).

4. "Discussion of the Meteorological Observations at the British Kite Stations, Session 1906-1907." By Margaret White, T. V. Pring, and J. E. Petavel, F.R.S. (p. 15).

December 18, 1907.

Ordinary Meeting.

Hugh Robert Mill, D.Sc., President, in the Chair.

Claud Andrew Allan, Darleith, Cardross, Dumbartonshire ;
Edward Heron Allen, 3 Northwick Terrace, N.W. ;
Allanson Bailey, Rothesay, Lemsford Road, St. Albans ;
Henry J. Bailey, J.P., D.L., Rowden Abbey, Bromyard ;
William Alcock Beck, B.A., Tower Bank, Sawrey, Ambleside ;
Charles Hugh Berners, J.P., D.L., Wolverstone Park, Ipswich ;
Charles Brown, J.P., Leycroft House, Weston-super-Mare ;
Miss L. H. Bushell, Hinderton Lodge, Neston, Cheshire ;
Charles Pratt Chambers, Orchard Head, Broughton-in-Furness ;
Harvey Ralph Goring Clarke, B.A., Brook House, Hayward's Heath ;
Alfred Clay, Darley Hall, Matlock ;
Humphrey B. Devereux, Waihi, New Zealand ;
Thomas Arthur Dickson, Sywell Hall, Northampton ;
James Dixon, J.P., Tylecote, Ranmoor, Sheffield ;
James William Duncan, The Firs, Castle Hill, Maidenhead ;
Rev. James Charles Fox, Temple Coombe, Somerset ;
Edward Pirie Gordon, J.P., Gwernvale, Crickhowell, Brecon ;
William Hall, Swerford, Enstone, Oxon. ;
Mrs. Marcus Hare, Court Grange, Newton Abbot ;
Joseph Hawksley, Assoc.M.Inst.C.E., 14 Albert Square, Great Yarmouth ;
Arthur Pearse Jenkin, F.S.I., Treevergie, Redruth ;
Charles Edwin Jones, Assoc.M.Inst.C.E., 31 Greycoat Gardens, S.W. ;
Owen Jones, Dollawell, Blaenau-Festiniog, N. Wales ;
Framjee Dorabjed Kapadia, Ahmedabad, Bombay Presidency, India ;

LEONARD G. KING, 32 Palatine Road, Withington, Manchester;
Miss I. J. R. MACADAM, 44 South Street, St. Andrews, N.B.;
WILLIAM GEORGE MACHIN, Hartley Witney, Winchfield;
PHILIP PENNANT PENNANT, Nantlys, St. Asaph, Flintshire;
J. E. PETAVEL, F.R.S., University, Manchester;
Miss F. J. SPARKS, Bincombe House, Crewkerne;
ALBERT JOHN STEPHENS, 39 Denmark Road, Gloucester;
WILLIAM STEAD STRACHAN, B.Sc., 9 Victoria Street, S.W.;
Capt. FRANCIS S. SYMONS, Kenilworth, Farnan Road, Streatham;
ARTHUR JOHN WALKER, M.A., Mount St. John, Thirsk;
Mrs. WILKIN, Summerhill, Tenterden, Ashford;
Miss E. D. WOODHOUSE, Burghill Court, Hereford; and
Miss J. L. WOODWARD, The Knoll, Clevedon, Somerset,
were balloted for and elected Fellows of the Society.

Mr. J. W. FORRESTER and Mr. T. P. NEWMAN were appointed Auditors of the Society's Accounts.

THE PRESIDENT said, that before proceeding with the papers, he could not refrain from giving expression to the feelings of all present at the immense loss to science sustained by the death of Lord Kelvin. He spoke the more feelingly because he knew how greatly Lord Kelvin had been interested in Meteorology, as in every other branch of physical science. He had the most catholic spirit of any scientific man in this country and of modern times, and he was interested in every scientific study, both as a man of science and as an eager and enthusiastic student of nature. Lord Kelvin's extraordinary youthfulness of character was perhaps the feature which first and always impressed every one who knew him. The last time he, Dr. Mill, had met Lord Kelvin, the latter had been speaking most enthusiastically about meteorological work in the recent Antarctic Expedition, and speculating on the origin of the Antarctic ice cap, and the nature of the land which it covered, as keenly as in the days long ago when he demonstrated the limit of possible thickness of the ice cap by the effect of pressure on the freezing point. He, the President, had had occasion to look up the names of William Thomson and Lord Kelvin in the Society's Bibliography of Meteorology, and there were so many entries that it would take too long to recapitulate them. Lord Kelvin's great work on Atmospheric Electricity was known to all, that on the Increase of Temperature within the Crust of the Earth was perhaps less remembered. By deductions drawn from the rate of cooling of the Earth, Lord Kelvin had reached back into the past and guessed at the beginning from the accumulated data of the present. He was always interested in the theory of Atmospheric Circulation, and keenly supported the claim of his brother, Professor James Thomson, to the priority of the statement of the atmospheric circulation, with which the name of Ferrel was more often associated in the text-books. Though the Society had, unfortunately, not been directly associated with Lord Kelvin, he, as President, could not allow the occasion to pass without referring to the irreparable gap made in the ranks of scientific men by the loss of Lord Kelvin, who summed up in himself so much of the history of physical science in the nineteenth century.

The following communications were read:—

1. "THE POSSIBILITY OF A TOPOGRAPHY OF THE AIR, BASED ON BALLOON OBSERVATIONS WITH SPECIAL THEODOLITES." By CAPTAIN C. H. LEY, F.R.Met.Soc. (p. 27).

2. "INDICATIONS OF APPROACHING FROST." By RICHARD STRACHAN, F.R.Met.Soc. (p. 47).

CORRESPONDENCE AND NOTES.

Prize Competition for Teachers.

The Council of the Royal Meteorological Society, being desirous of encouraging the teaching in schools of facts regarding Weather and Climate, invite elementary teachers and others to send in essays on Weather or Climate in the form as given in the particulars below.

The Council are hoping by means of this competition to find out what kind of instruction on the subject of Weather is given to the scholars in the Elementary Schools. They believe that many teachers do impart much interesting and valuable information, and also help their scholars to keep records of the weather.

In the present competition the Council require that an original sketch of a Nature Study Lesson on Weather or Climate (not exceeding 1500 words) should be sent in, together with a brief summary of five other lessons to cover the whole subject of Weather and Climate.

It is desirable that the competitor should state for what Standard he (or she) considers the lessons to be suitable.

If essays of sufficient merit are received, three prizes will be awarded of £5, £3, and £2 respectively. All the competing essays will become the property of the Society, and the decision of the Council as to the awards shall be final.

The essays should be signed by the writer, and sent in on or before January 31, 1908.

Lectures on Meteorology.

Royal Meteorological Society.—During the past three months Mr. W. Marriott has given lectures on meteorological subjects in connection with the Society's scheme for diffusing a knowledge of meteorology at the following places:—

October 28.—Newcastle-on-Tyne, Literary and Philosophical Society.

November 1.—Brighton and Hove Natural History and Philosophical Society.

November 4.—Winchester, West Downs School.

November 14.—Keighley, Literary and Scientific Society.

Royal Geographical Society.—A course of six lectures on "The Geographical Distribution of Rainfall in the British Isles" will be given by Dr. H. R. Mill, in the Meeting Room of the Society, on Thursday evenings in January and February, beginning on January 23 at 6 p.m. The syllabus of the Lectures is as follows:—Lecture I. The physical geography of Great Britain and Ireland. Lecture II. Rain; its nature, origin, and functions. Lecture III. Measuring, recording, and mapping rainfall. Lecture IV. The duration and distribution of showers. Lecture V. Average annual rainfall; and Lecture VI. Rainfall in relation to configuration and economic conditions.

University of London.—A course of twelve lectures on "Meteorological Organisation and Methods of dealing with Meteorological Observations" is being given by Dr. W. N. Shaw, F.R.S., the Director of the Meteorological Office, and University Reader in Meteorology, at the University, South Kensington, on alternate Mondays at 5 p.m. The first lecture was given on October 21, 1907. The syllabus is as follows:—

METEOROLOGICAL OBSERVATION.—Instruments, observatories, and stations. Measurement of pressure, temperature, humidity, wind-velocity. Estimation and observation. Cloud forms and velocities. Methods of investigation of the upper air.

METHODS OF DEALING WITH METEOROLOGICAL OBSERVATIONS.—Local differentiation and combination. Maps. Means and averages. Harmonic analysis. Periodicity. Correlation.

Cambridge University.—Mr. E. Gold will give a course of eight lectures in Meteorology, at the Cavendish Laboratory during Lent term, on Thursdays at 5 p.m., beginning on January 16. The syllabus is as follows:—

Lectures I. to IV., THERMO-DYNAMICS OF THE ATMOSPHERE.—Changes in a mass of air containing water vapour, which rises adiabatically or pseudo-adiabatically. The dry, rain, hail, and snow stages. The deductions of Hertz and von Bezold. Graphical representation. The potential temperature. Vertical temperature gradient deduced from kite and balloon observations. Formation of atmospheric waves. The changes produced by mixing quantities of air of different temperatures and humidities. Paradoxical result of mixing cold damp air with warm dry air. Methods of cloud formation. The solar halo.

Lectures V. to VIII., ATMOSPHERIC MOTION.—The general circulation. Theories of James Thomson, Ferrel, W. von Siemens, Oberbeck. Comparison with surface currents and with upper currents deduced from cloud observations. Distribution of isobars at higher levels. Local circulation. Relation between pressure-gradient and wind velocity. Characteristics of cyclones and anti-cyclones. Work of Diro Kitao. Formation of cyclones. Theories of Ferrel and Faye. Tropical cyclones and tornadoes. Theorem of Poincaré for angular velocity in symmetric atmospheric vortex. Results of upper air observations of wind velocity.

The Study of the Weather as a Branch of Nature Knowledge.

Dr. M. I. Newbigin recently delivered a lecture on this subject to classes of teachers at Aberdeen and Edinburgh, which is printed in full in the *Scottish Geographical Magazine* for December 1907. This is an interesting Nature Study Lesson, very much on the lines suggested by the Council of the Royal Meteorological Society.

Dr. Newbigin says:—"In endeavouring to suggest to you methods of studying the weather in schools as a part of nature knowledge, it may be well to begin by considering very briefly the aims which should inspire a course in nature study, for our methods will be naturally largely influenced by our aims. The object of such a course is, I take it, twofold. We want, in the first instance, to train the powers of observation and develop the intelligence, with the view not only of making better citizens, but also of increasing the happiness of life; and, in the second place, we want to give an insight into the methods of science. To show that the methods of science are everywhere in essence the same, and to suggest that, owing to the fact that the further scientific research is carried, the more obvious it becomes that nature is orderly and uniform, and that there are, therefore, few series of phenomena too trivial to be worth study by some one—these, in my opinion, are points of great and increasing importance. Again, even elementary education is incomplete unless it succeeds in imparting some flavour of real enthusiasm for science.

"When we come to practical detail I suppose most of you, as practical teachers, have felt that the supreme difficulty is to find what we may call a jumping-off point. I heard the other day an interesting story of a little girl who objected strenuously to going to school, because, as she said with much force, 'They don't teach me anything I want to know.' This is probably a condition that frequently occurs, but in the teaching of such subjects as arithmetic and spelling we have behind us the driving force of parents and relatives who say, with a truth that even the child recognises, that adult life is impossible without a certain amount of knowledge. In nature study in

general we have not as yet this advantage, and have even to allow for the fact that the parent in the background is probably saying, 'Tadpoles and dandelions are all very well, but that won't help you to earn your living.' It is, therefore, very important to include in the course subjects about which the child does want to know, in which there is an initial interest to help us over the drag at the start. Now the weather is our basal subject of conversation, interests us at every turn of life, and as even the child feels this interest, the subject is one well worthy of the attention of teachers of nature study. Again, the uncertainty of our weather has become a proverb, the difficulties of forecasting not less so, and yet when we study weather in detail, we find that, although we can say very little as to the possible weather next week, and almost nothing as to its probable course next month, yet the annual series of changes which make up the climate of a locality take place in orderly sequence, and almost all the elements of the total are more or less fixed and constant. The fact that from one point science means the finding of order in apparent chaos may thus be well brought out. One must not also forget that the child is eminently practical and utilitarian, and we are not only all naturally interested in weather, but in a maritime country it is of great practical importance. In a coast town like Aberdeen one has the coastguard station as an evidence of this practical interest, and one can even hope to show that coastguard station, *Nautical Almanac*, and Meteorological Society form a sequence, illustrating the fact that science is merely enlightened and developed common sense and common experience."

Dr. Newbigin then proceeds to give an interesting and simple lesson on the study of the weather. He concludes as follows:—

"My aim in this lecture has been both to show what there is to teach in connection with weather, and to suggest methods of teaching it. As is the case in practically all the sciences, the great difficulty is to combine in a rational way the method of direct observation and of instruction, so as to give the taught something in the way of a practical appreciation of the subject. If I may recapitulate my suggestions, I should say, begin first by the most general and simple observations of wind and sky, sunshine and rain. Then introduce the barometer, and get a series of observations sufficient to answer a series of questions, such as: Does the barometer move or not? much or little? does the wind affect it? the temperature? rain? At first, at any rate, I should be disposed to let the class take observations for a school week at irregular intervals rather than continuously, and then let them compare different weeks until they gradually acquired some notion of the meaning of average height. After the interest had been aroused it would be a good plan to give a series of more detailed lessons, and gradually introduce the consideration of cyclones and anticyclones, the reading of weather charts, and so forth. One would naturally take advantage of outstanding meteorological events as texts—a great storm such as that which wrecked the *Berlin*, a long frost, our late fine Easter: any one of these would form an interesting starting point. As I have tried to show also, the subject may be correlated in many different ways with the ordinary geography lesson, or even with history, for climate has had much to do in making the British what they are, and climate is merely the average succession of weather. Especially, however, I should lay stress upon the attempt to employ meteorological phenomena as a stimulus to the imagination, and I should urge the value of introducing in occasional lessons conceptions which in their entirety may be beyond the reach of the class, but of which they can be made to understand enough to greatly interest them. I have great faith in Anatole France's dictum that a child's feelings may be intensely roused by subjects which are, strictly speaking, beyond his intellectual reach. I should strive to make clear, for instance, something of the romance

of a meteorological map, to picture the many patient observers, widely separated from one another, who, day by day, records each his quota of facts—facts whose full significance the individual cannot at the time fully see, but which he registers in the certain knowledge that they will fit into a clear and coherent whole. Man, now no more than ever he could, can alter the course of the winds, but within limits he has now so far conquered nature that he can tell whither they come and where they will go, he has conquered time and space so far that he can send warnings of coming changes. Here, surely, are facts which are worth knowing, suggestions which are worth making. Again, though the meteorological map is an extraordinary triumph of skill, it has still many gaps. The meteorologist is still groping after that perfection of his methods which will enable him to prophesy without any fear of error, and his science has not the frigidity of perfection, but the perennial interest of an evolving organism. In our own British weather maps, so apparently a trifling matter as the opening of the cable to the Faröes and Iceland has greatly increased the value of the forecasts.

"I do not wish to claim for the study of the weather any monopoly of merit, but only to suggest that if I am right in my statement of the aims which should prompt the teacher of nature study, it is a branch which is well fitted to carry out these aims."

RECENT PUBLICATIONS.

Meteorology in Mysore for 1906, *being the Results of Observations at Bangalore, Mysore, Hassan, and Chitaldrug.* Fourteenth Annual Report. By JOHN COOK, M.A., F.R.S.E. Bangalore, 1907. 4to. 18 + 122 pp. and 9 plates.

In addition to the usual information given in these annual Reports, the present volume contains a set of tables of "Daily Means" for the twelve years 1893-1904, for each of the four Observatories at Bangalore, Mysore, Hassan, and Chitaldrug. In accordance with the recent action of the Government of India, which has reduced the great majority of its second-class observatories to third-class ones, the Hassan and Chitaldrug observatories will for the future be of the third class, and will therefore record merely the 8 a.m. observations daily.

The Climate of Abbassia near Cairo. By B. E. F. KEELING. Survey Department paper, No. 3. Cairo, 1907. 61 pp. and 8 plates.

This is a summary of 35 years' observations made at the Observatory, which was founded in 1868, principally for meteorological work, by the Khedive Ismail Pasha. The Observatory was maintained continuously at Abbassia till the end of 1903, when it was removed to Helwan. Since that date a second order meteorological station has only been continued at Abbassia. Previous summaries of the work of this Observatory have from time to time appeared, viz. a very detailed paper, "Notice sur le Climat du Caire," published by M. J. Barois in 1889, in the *Bulletin de l'Institute Égyptien*, and a summary of 30 years' observations in the *Annual Meteorological Report of the Survey Department* in 1898-1899. After the date of the latter of these summaries there were 5 years' observations before the removal of the Observatory, and in the paper under notice a summary of these 5 years' observations and the mean values for the 35 years are given. It has not been possible to treat the results in a homogeneous manner, owing to the fact that the instrumental equipment

has not been uniform. The results have been summarised as far as possible in the form of tables, the descriptive part being confined to the limits necessary for explaining them. Summarised climatological tables are given, and for each of the principal meteorological elements necessary for corrections, to reduce the means deduced from the present readings made three times a day to the true daily mean published before the closing of the Observatory, are given. The paper also contains charts showing the annual and daily curves obtained for each of the principal elements. The following table shows the mean results for 17 years, 1887-1903 :—

MEANS OF CLIMATOLOGICAL OBSERVATIONS AT ABBASSIA, CAIRO, 1887-1903.

MONTHS.	Temperature.						Relative Humidity.[2]	Rain.
	Means.				Extremes.			
	Min.	Max.	Range.	Mean.[1]	Min.	Max.		
	°	°	°	°	°	°	%	in.
January	44·2	64·9	20·7	54·1	30·7	79·9	68	·27
February	46·8	69·6	22·8	56·8	34·2	95·9	64	·16
March	50·0	75·6	25·6	62·4	37·8	106·2	58	·16
April	55·0	83·7	28·7	70·2	42·3	108·7	50	·08
May	60·8	90·9	30·1	76·8	48·2	111·6	46	·04
June	65·1	95·2	30·1	81·9	56·7	113·4	46	...
July	69·4	97·2	27·8	83·5	60·8	111·7	50	...
August	69·4	94·8	25·4	82·6	59·9	106·9	55	...
September	66·0	90·0	24·0	78·1	56·3	105·1	61	...
October	62·8	86·0	23·2	73·2	51·4	107·8	65	·04
November	54·3	75·7	21·4	65·1	38·3	92·5	66	·20
December	48·2	68·4	20·2	57·9	34·3	84·9	70	·23
Year	57·7	82·7	25·0	70·2	30·7	113·4	58	1·18

[1] 35 years, 1869-1903. [2] 33 years, 1871-1903.

The Rainfall of the Philippines. By the Rev. M. S. MASO. Prepared under the direction of the Rev. J. ALGUÉ, S.J., Director of the Weather Bureau, Manila, 1907. 4to. 32 pp.

This statement of rainfall in the Philippine Archipelago was prepared in 1905 at the request of the Solar Commission. Except for Manila, whose uninterrupted records extend back to the year 1865, and for a few other stations which have reported the rainfall during ten or more years, there has not been a very extensive series of observations to work on. Considering, however, the relative small area of the Archipelago, the data given in the paper convey a very fair idea of the nature and variation of the rainfall in the Philippine Islands. Detailed results of monthly rainfall at sixty-four stations for varying periods are given, and the subject is dealt with under the following heads :—

1. Summer and autumn rainfall ; cyclonic rainfall.
2. Winter or north-east monsoon rainfall ; and
3. Spring rainfall : March, April, May.

The mean yearly amount of rainfall is really high in the whole Archipelago, but its effect depends principally upon its distribution throughout the year. In respect to rainfall, three different climates can be distinguished in these islands.

The first, and worst of them, has two well-defined seasons, wet and dry. This climate prevails in those regions which during the summer months

receive more than 80 per cent of the annual rainfall, and consequently have five rainy months and practically seven of drought. Such regions are those facing the China Sea, the low plains extending northward and eastward from Manila Bay, the moderately high and hilly lands surrounding these plains, and the part of the provinces of Luzon, facing the southern seas with mountains to the north. The same climate is found also in some valleys and plateaus extending along the central mountain range of Luzon, as Baguio (4780 feet above sea-level).

The second climate consists of eight or nine months of rain and three or four of drought, the percentage of rainfall being high during both the summer and winter season. This climate prevails in the eastern and south-eastern parts of Luzon, and in the central Visayas, where the North-easters blow almost without any obstacle.

The third and best climate is that which results from a fairly even distribution of the rainfall over the whole year, and consequently shows a quite uniform percentage for the three different seasons—summer and autumn, winter, and spring months. This climate is found south of the fourteenth parallel only, being enjoyed by some regions of south-eastern Luzon, the eastern Visayas, Mindanao, and Jolo. The western part of Mindanao, as is shown by the records of Zamboanga, is the region of the whole Archipelago which receives the smallest amount of annual rainfall; but this deficiency is largely counterbalanced by a fairly regular distribution, so much so, that the tropical climate of Zamboanga is considered as one of the best in the Archipelago.

In the island of Luzon, the province of Nueva Vizcaya, situated about 1300 ft. above sea-level, has only 26·7 ins. of annual rainfall, but this is very well distributed. The adjacent wide and long valley, comprising the provinces of Isabela and Cagayan, has likewise a fairly good distribution, in fact far better than that in the western provinces of Luzon. The rainfall distribution at Baguio, 4780 ft. above sea-level, must be regarded as rather abnormal, due to some peculiar local conditions, because it really differs from that observed in the other highlands of the Archipelago.

A few stations which have a very great and quite abnormal annual rainfall must be mentioned. These are Masinloc, on the Zambales coast of Luzon, facing the China Sea, with 157 ins.; Mamburao, on the western coast of Mindoro, with 125 ins.; and Tandag, on the eastern coast of Mindanao, with 174 ins. Although these averages are based on the observation of only two years, they are considered to be sufficiently reliable, owing to the special local conditions of these stations. Masinloc is situated at the head of a large bay open to the China Sea. At a distance of a few miles to the east a rather steep mountain range, some 4000 ft. high, runs in a north to south direction. Hence the district receives the full force of the Western and South-western winds, which, striking the near-by slopes, take an ascensional movement, and discharge the immense amount of moisture which they hold upon the narrow strip of land and the mountain slopes. The location of Mamburao is very much like the one just described. Tandag lies likewise at the head of a bay, which is rather small, open towards the north-east, and surrounded by hills covered with dense forests. The moist North-east winds rush into the funnel-shaped opening, take an ascending direction, and discharge the greater part of their moisture as abundant precipitation.

The following is a summary of the different climatic zones of the Archipelago:—

1. Zone of very definite rainy and dry seasons:—

The western coasts of Luzon, from Cape Santiago to Cape Bojeador, including the western part of Manila Bay; the western coasts of Mindoro and Panay

and the Calamianes group; the central plains and moderately high lands of Luzon, from Batangas to Nueva Ecija and Pangasinan; the region of Benguet. The yearly amount of rainfall is above 80 ins. in the western section and in Benguet, while in the central section it is between 60 ins. and 80 ins.

2. Zones or regions with long rainy season, including the summer, autumn, and winter months, and consequently with a very short dry period:—

The northern and eastern coasts and the south-eastern part of Luzon, including the Cagayan and Isabela valleys; Batanes and Babuyanes Islands; the central Visayas, as Romblon, western Cebu, northern Panay, and Negros; the northern part of Mindanao. The annual amount of rainfall is very great, above 120 ins. in northern Panay; above 80 ins. in northern and eastern Luzon, Batanes, and Babuyanes islands, northern Negros, and Romblon; moderate, that is, below 80 ins., in the Cagayan valley of Luzon and in northern Mindanao.

3. Zones with more or less uniform distribution of rainfall over the whole year:—

The south-eastern end of Luzon; the eastern Visayas, Masbate, Samar, Leyte, Bohol, Camiguin, eastern Cebu, eastern and southern Negros and Panay; the eastern and southern coasts of Mindanao; Basilan and Jolo; the relatively high and hilly province of Nueva Vizcaya in Luzon. Within these regions the annual rainfall surpasses 120 ins. in some coast stations of south-east Luzon, eastern Samar, and Mindanao. In the rest it varies between 80 ins. and 120 ins., except in eastern Cebu, south-west Leyte, southern and central Mindanao, Basilan, Jolo, and Nueva Vizcaya in Luzon, where the yearly amount remains below 80 ins.

METEOROLOGICAL LITERATURE.

The following titles of papers bearing on Meteorology have been selected from the contents of some of the periodicals and serials which have been received in the Library of the Royal Meteorological Society. This is not a complete list of all the published meteorological articles, but only shows those that appear to be of more general interest.

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Aitken, J.—Hygroscopes. *Symons's Meteor. Mag., London*, **42**, 1907 (187-188).

[Baden-Powell, B.]—Fog Dispersion. Facts and Fallacies, by the Editor of "Knowledge." *Daily Graphic, London*, Nov. 12, 1907.

Barus, C.—On Distribution of Nuclei in dust-free wet Air, and on Methods of Observation. *Proc. Amer. Phil. Soc., Philadelphia*, **46**, 1907 (70-79).

Bates, Rev. D. C.—The Study of Weather Phenomena. *Symons's Meteor. Mag., London*, **42**, 1907, (117-129; 198-202).

Belden, W. S.—Special Temperature Observations made on Low Ground in the Vicinity of Vicksburg, Miss. *Monthly Weather Rev., Washington*, **35**, 1907 (219-221).

Bentley, W. A.—Studies of Frost and Ice Crystals. *Monthly Weather Rev., Washington*, **35**, 1907 (348-352).

Bigelow, F. H.—Studies on the Phenomena of the Evaporation over Lakes and Reservoirs. *Monthly Weather Rev., Washington*, **35**, 1907 (311-316).

Birdwood, Sir G.—The Mechanism of the South-West Monsoon. *J. Soc. Arts, London*, **55**, 1907 (1070-1072).

Birdwood, Sir G.—The Phenomenon of the South-West Monsoon. *J. Soc. Arts, London*, **56**, 1907 (33-35).

Bonacina, L. C. W.—The Effects of Exposure to Wind upon the Amount of Rain caught by Rain-Gauges, and the Methods of protecting Rain-Gauges from them. *British Rainfall*, **1906**, *London*, 1907 (27-45).

Bonacina, L. C. W.—Rain-Gauge Exposure and Protection. *Nature, London*, **76**, 1907 (672-673).

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Chree, C.—Auroral and Sun-Spot Frequencies contrasted. *Proc. Physical Soc., London*, **20**, 1907 (434-452).

Coblentz, W. W.—Barnes's Ice Formation with special Reference to Anchor Ice and Frazil. *Monthly Weather Rev., Washington*, **35**, 1907 (225-227).

Coffey, G. A.—Influence of Temperature and Moisture upon the Rate of Growth of Tobacco. *Monthly Weather Rev., Washington*, **35**, 1907 (346-348).

Cottier, J. G. C.—A Summary of the History of the Resistance of Elastic Fluids. *Monthly Weather Rev., Washington*, **35**, 1907 (353-356).

Curtis, R. H.—The Distribution of Sunshine over the British Isles. *Symons's Meteor. Mag., London*, **42**, 1907 (147-151 and pl.).

Cyran, G.—Die Trockenheit des Jahres 1893 in Mitteleuropa. *Wetter, Berlin*, **24**, 1907 (182-186, 203-207).

Dike, P. H.—Paulsen's Resumé of Recent Theories of Polar Lights. *Terrestrial Magnetism and Atmospheric Electricity, Baltimore*, **12**, 1907 (84-86).

Dobrowolski, A.—Les cristaux de glace aériens et le phénomène des halos. *Ciel et Terre, Brussels*, **28**, 1907 (305-312, 336-342).

Eliot, Sir J.—A Discussion of the Anemograph Observations recorded at Allahabad from September 1890 to August 1904. *Memoirs, Indian Met. Dept., London*, **18**, 1907 (283-371 and 13 pl.).

Eliot, Sir J.—A Discussion of the Anemographic Observations recorded at Lucknow from July 1878 to October 1892. *Memoirs, Indian Met. Dept., London*, **18**, 1907 (373-430 and 15 pl.).

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MAP-STUDIES OF RAINFALL.

BY HUGH ROBERT MILL, D.Sc., PRESIDENT.

[An Address delivered before the Royal Meteorological Society, January 15, 1908.]

(Plate 1.)

IT is good for a Society to have a wide range of selection when appointing a President for the year, and a kindly provision which gives the occupant of the chair a second chance, so that learning by experience he may haply make a wiser use of his opportunities after the first term. Amongst the past Presidents—not a few of whom are happily present—there have been men of distinction in many walks of life to whom the science of meteorology appealed in various ways. On examining the list of the twenty-eight previous Presidents (for though there were thirty previous presidentships two served the office twice) one finds that they were as nearly equally divided as the total number will permit between astronomers, medical men, engineers, professed meteorologists, and others. This gives variety and the advantage of numerous points of view, for the subject and treatment of the address necessarily depend largely on whether meteorology was to the President of the year the matter of his daily work, a science related to that which he pursued, an aid in the study of his profession, or the delight of his leisure hours. From each point of view it is possible to see some special aspect of meteorology in a fresh light and in a way that appeals more forcibly than any other to particular minds.

Last year my predecessor opened to us a fascinating chapter of history illuminated, or as often overshadowed, by the influences of weather. That address appealed delightfully to every one save only the unhappy President-designate, who well knew that he could not bring forth from his treasury things new or old so pregnant with human interest.

Belonging as I do to those who spend their whole time in meteorological work, I suffer to the full from the curse of the specialist—want of

time to keep abreast of the contemporary progress of his own science as a whole. Hampered by routine—which must be fulfilled at fixed dates,—one in my position finds that opportunities of conducting researches, pondering over generalisations, or following out lines of thought, even in his own department, occur rarely and in fragments. Such a position predisposes to the torture of Tantalus. To live by a swirling stream of data that one can scarcely keep in its channel; to see lines of fruitful investigation open up and wheel aside like the furrows of a ploughed field from a railway carriage; to realise with each recurring year that the new harvest being gathered in is only adding to the store which is never being fully utilised,—is enough to make the most fastidious purist in language mix his metaphors.

I can only speak on such an occasion as this of my own work, for it leaves me no time to look at other things, and hence I invite you, though with some misgivings, to enter the rather rough and infertile corner of the great field of meteorology which I till, and to see something of the methods which appear likely to lead to its improvement. The specialist situated as I have indicated can at least claim one advantage over the student of many books, and that is no small one, for he learns to test his data before using them and to misdoubt the conclusions of others before testing them.

I must speak of rain, and even then only of the rain that falls from the currents and eddies of air that drift across these islands lying between the Continent and the deep sea. The special problem I have before me (which I greatly fear I may have to leave unsolved behind me) is to determine the normal annual rainfall of the British Isles in relation to the general configuration of the land, and to ascertain how the rainfall of individual years and months, and even of the constituent showers, is related to the normal.

The most useful method of working towards this end is by the preparation and study of maps of rainfall, and as that method is not yet familiar to the public, or even to some persons interested in meteorology, I propose to attempt in this address to deal with map-studies of rainfall. Time has not come my way to allow of the preparation of a complete memoir, and I can present this only as a fragmentary contribution to cartometric hyetography.

The map as a means of meteorological expression has been greatly used by the weather services of all countries, and by none more effectively than by our own Meteorological Office. I can claim novelty for nothing I have to say, but novelty is not the only element of interest or of value on such an occasion as the present.

Rainfall maps are by no means new, and a good deal has been written on the principles which ought to guide their construction. A historical review of the subject does not come into the present scheme, and is not omitted accidentally. One or two preliminary points have to be touched on. Isohyetal lines, *i.e.* lines which divide two contiguous areas in one of which the rainfall is lower and in the other higher than a given amount, are precisely similar to contour lines of level, or isobars or isotherms. The only difference in constructing a rainfall map and a map of temperature or pressure is that no correction for elevation above sea-level has to be applied, the rainfall depths being referred to the

actual surface of the land at the place of observation; so that the colouring of a rainfall map appeals directly to the eye, presenting the actual conditions without any qualification, and requiring no mental correction as a pressure or temperature map does.

The distribution of rainfall is to a large extent dependent on the local configuration of the land, and, therefore, it is necessary to have a far greater number of points from which to construct a map of rain than in the case of pressure, which is an affair of the air alone, or of temperature on which the influence of land is less dominant.

Thanks to the remarkable insight and unflagging diligence of the late Mr. G. J. Symons, the number of observers of rainfall in the British Isles has increased from a few hundreds in 1860 to more than 4500 at the present time. These observers are actuated by many motives; but the work being done for their own purpose, they all send in their records to the historic Rainfall house in Camden Square, where Symons brought the British Rainfall Organisation to maturity, and where all the records collected by him and since his time are preserved for reference. A few of the records received every year are bad, a considerable number indifferent, but the vast majority are of surprising excellence, showing an amount of vigilance and conscience that do honour to the community. Every record that is received is critically examined, and many errors are detected and corrected as a result of the comparison of one record with its neighbours. The total annual rainfall is published in *British Rainfall*, and various aspects of the fall of rain in space and time are discussed with some detail. It is not necessary to refer at present to these discussions. They are conducted on the broad lines laid down by Mr. Symons, and where they have varied from the traditional mode of treatment it is mainly by the development of cartographic and cartometric methods.

The material for map studies of British rainfall is contributed by the thousands of observers past and present, whose organised and united work forms a vast structure of mutually supported facts such as it falls to the lot of few men of science to deal with. To these observers students of meteorology owe a debt that we can scarcely realise, and are quite powerless to acknowledge adequately; but it is impossible for me to touch on this subject before this audience without offering the tribute of the fullest recognition to the rainfall observers of the country.

When the philosopher Kant divided the communication of experience into two categories: the historical or relation in order of time, and the geographical or relation in order of space,—he suggested the two methods of treating all natural phenomena subject to variation in different places at the same time, and at different times in the same place. The historical method of studying rainfall is the more attractive, for it leads us into the temptation of endeavouring to project the light of the past upon the future, and by observing former recurrences of wet and dry periods to predict what the next year or month will bring forth. I do not say that this path of research should not be pursued, but it is both difficult and dangerous. Although even cycle-hunts are not to be discouraged when the scientific sportsman is gifted with a critical and unbiassed mind, at present I am only treading the safe and unadventurous path of geographical distribution, and I think there are reasons for believing

that that path may lead us far towards more than one important conclusion.

In considering the distribution of rainfall, as in considering any other problem scientifically, we require to use terms with a definite meaning, and I hope that I may be excused for assigning definite meanings to familiar English words instead of importing classical terms which, despite a grander display of syllables, can mean no more. For convenience I use the term *mean* as indicating the sum of any number of figures divided by that number, reserving the word *average* for the mean of a number of figures representing values in order of time. Thus the mean of thirty annual rainfall values is spoken of as the average rainfall for thirty years. The mean of a number of uniformly distributed figures representing the distribution of rainfall in space I speak of as the *general* rainfall of the area concerned; thus the mean depth of rainfall over England for any day, month, or year, is the *general rainfall* of England for that particular day, month, or year. The mean of the general rainfall of England for thirty years is expressed as the *average general rainfall* of England for thirty years. A line passing through points having the same rainfall is an isohyetal line, or *isohyet*—the term having been already introduced is retained on account of its similarity to isotherm and isobar. The line joining successive positions of the centre of an atmospheric depression or cyclone is the *track* of the depression. The isohyetal lines representing the distribution of rainfall in a shower may be termed the *splash* of the rainfall, and the isohyets representing the rainfall of one or several days for a considerable stretch of country along the track of a depression, which is the generalisation of a succession of splashes, may be called the *smear* of the rainfall of that depression. These are all the special terms which it will be necessary to use.

The map which forms the basis of any work on the geographical method must, of course, be accurate and expressive. Fortunately we have in the work of the Ordnance Survey a basis of unimpeachable accuracy reproduced on a great variety of scales. The six-inch map is rarely required in rainfall work, except for the purpose of ascertaining the altitude of stations above sea-level, and the one-inch map is useful mainly in fixing the exact position of gauges. For the purpose of preparing maps of the rainfall of counties, or similar small areas, the quarter-inch scale is the most convenient, the hill-shading in the new edition being very effective; and in a few instances the half-inch maps combining both hill-shading and contours can be utilised. Bartholomew's series of maps on the scale of half an inch to a mile is in some cases a better basis for rainfall work than the Ordnance Survey maps on the same scale, on account of the greater contrast presented between high and low land, and the absence of the too conspicuous colouring of woodlands which, from the present point of view, are distracting features on the Ordnance Survey coloured sheets.

In mapping the rainfall of the British Isles, it is convenient to have the whole country represented on one sheet with a great number of place-names by which to find the position of stations easily and exactly. For this purpose the 10-mile-to-an-inch Ordnance Survey map is too large, and I generally use a special edition of Bartholomew's Railway Map, on the scale of 19 miles to an inch, and measuring 34 ins. by 30 ins. It is printed in pale grey so that pen-work stands out clearly upon it, and

there are two tints of shading distinguishing the land over 500 feet and over 1000 feet above sea-level respectively. For purposes of semi-diagrammatical representation it is sufficient to use a mere outline map, perhaps with a few rivers and names to guide the eye; but in such cases, for instance, as the rainfall maps published in the *Monthly Weather Report*, the isohyets are copied from the original plotting on detailed maps on a much larger scale. The map of rainfall expressed by means of isohyetal lines may be used either qualitatively, as representing the distribution of rain in a graphic form, or quantitatively, for the purpose of measuring the amount of rain falling on a given area. The former purpose will claim most of our attention this evening, although the latter is no less important.

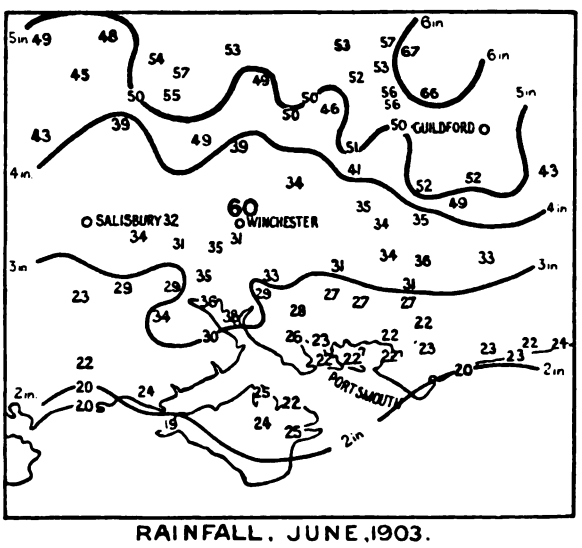

FIG. 1.—Map showing the Detection of an Erroneous Return.

The first use of maps in the routine of the collection of data in the office of *British Rainfall* is as a detective agency for the discovery of accidental errors. The monthly totals from about 700 stations are entered upon a map of the British Isles as they are received, and isohyetal lines are drawn for each inch, and sometimes, when the range of rainfall is small, for each half-inch. It is almost always found that the rainfall varies from point to point in a regular manner, though not always in the same way, and when one figure is observed much larger or much smaller than those surrounding it, a careful examination of the record almost invariably shows it to be in error. A neat example is shown in the annexed map (Fig. 1), which gives in tenths of an inch the rainfall for a month. The figure 60 north of Winchester was ultimately acknowledged by the observer to be a mistake for 36. When the same station shows a discordant figure month after month, the error is almost always traced to some imperfection of the rain gauge or some mistake in its exposure. Wilful errors on the part of observers are so very rare that I cannot say I have ever been able to satisfy myself as to one. Now and again, it is true, an

individual anxious to prove the dryness of his neighbourhood may neglect small falls, now and again another may give undue importance to such small falls, but as a rule observers' errors are due to honest mistakes or simple carelessness. The commonest sources of systematic error are reading the gauge at some hour other than 9 a.m., or entering the result to the date of reading instead of to the previous day. It is obvious that erroneous returns are most easily detected in the crowded parts of the map.

Annual returns are plotted in the same way, but the figures to place upon the map now amount to thousands instead of hundreds, and the isohyets, which can be defined with much greater detail, must be drawn at intervals of 5 or sometimes 10 inches; but the discordance of erroneous observations is none the less apparent, and errors due to instrumental deficiencies which were too small to show in the monthly figures may emerge into prominence on the annual map. The comparison of one record with a number of others in MS., or in printed form, is a slow and tedious process, whereas the comparison of the figures placed upon a map is simultaneous and almost automatic.

The detail with which the isohyetal lines can be drawn depends on the number of points for which data are available and on the uniformity of their distribution. Cases occur, however, where irregular distribution is a help, when, as rarely happens, observations are most numerous in places where the rainfall changes much in a short distance, and least numerous in places where there is little variation.

The rainfall map, after plotting all available figures and before drawing the isohyets, makes those parts of the country where observations are fewest very conspicuous by their blankness, and so directs attention to the districts where additional observers have to be sought. Attention may be called incidentally to a method of representing the density of population of rainfall observers, who number about 1 in 10,000 of the population of the British Isles, by shading distinctively the areas where there are more than twenty rain gauges in each 100 square miles, those in which there are more than one rain gauge in each 100 square miles, those areas more than 5 miles, and those more than 10 miles from the nearest rain gauge (see Plate 1).

On a large scale map it is impossible to draw isohyets across the blank spaces with any confidence as to minute accuracy, though the general run of the lines can usually be approximated to by following the prominent physical features of the country, or by preserving a general congruence with the curves for which there are data sufficient. It is difficult as yet to lay down rules, but experience brings facility in overcoming these difficulties, and two persons accustomed to draw such maps usually arrive at the same results. There is particular gratification when, as has more than once occurred, returns from the centre of a blank area have come in after the map was drawn, and the observed value fits so well that it does not require a line to be deviated for its accommodation. Ultimately it may be found possible to formulate certain relations of distance, altitude, and configuration, which will enable us to deduce with certainty the distribution of rain in an area without observers, provided it is surrounded, though perhaps at a considerable distance, by rainfall stations.

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The study of daily rainfall by making isohyetal maps is beset by a few special difficulties. The record used must be "perfect," that is to say, it must represent the result of examining the rain gauge at 9 a.m. on every day in the year whether rain has fallen or not, and the amounts must be entered to the date of the commencement of the 24

FIG. 2.—Map of Heavy Rain.

hours the reading for which is recorded. Although every year shows improvement in the directions of accuracy and uniformity, it is still very difficult to draw a rainfall map of a large area for a day of light rainfall. The rainfall of two days is apt to be confused, or a small fall may be omitted on its proper day and swell the amount on some other date. In the case of a very wet day, say the wettest day of the year, for any small area, mapping becomes quite easy, and one may have

complete confidence in the result. Falls of more than one inch of rain as a rule stand out conspicuously, and serve as index marks by which the trick of entering the readings to the "wrong day" may in most cases be readily detected.

For the last seven years maps of the rainfall on the wettest days

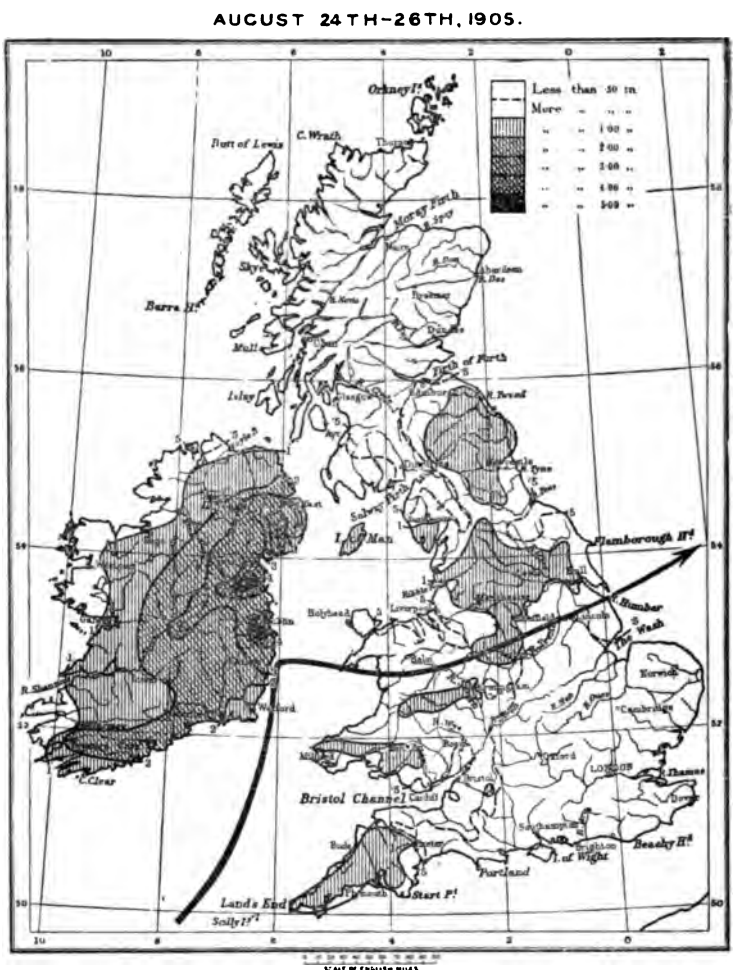

FIG. 3.—Map of Heavy Rain.

have appeared in each issue of *British Rainfall*, and the study of these maps reveals some interesting facts. A heavy rainfall, it is seen, rarely prevails over a wide area, and it is sometimes very restricted indeed. Two types of rain distribution on wet days may be distinguished as (*a*) the small, narrow, and often radiating splashes of thunderstorm rains, and (*b*) the wide uniform smears of the rain accompanying cyclonic disturbances. Both varieties of heavy rain have this in common, that they

fall impartially on high ground or low ground, their incidence and outline showing no apparent relation to the configuration of the country. It seems, on studying the maps of a large number of wet days, that the causes determining the fall of the rain on these occasions are to be sought in the air alone, and that at a level so far above the surface that inequalities of ground, even amounting to several thousand feet, are without direct influence upon them. It is perhaps too soon to speak with certainty on this subject, as heavy falls of the two types on individual days have not yet been mapped in every part of the British Isles—nor very often in any part; such instances as are available point to the general conclusion stated.

The natural unit to adopt in mapping heavy precipitation is not the day, for heavy falls of the thunderstorm type are of such intensity that the full amount, even up to three or four inches, usually falls in from one to three hours only; whereas heavy falls of the cyclonic type are usually gentler, but more persistent in character, so that the precipitation may require many hours in which to accomplish itself, and may even extend without intermission over parts of three days. The remarkable cyclonic rain of June 13-15, 1903, in the lower valleys of the Thames and Lee lasted for close on 60 hours. Thus in mapping thunderstorm rains the day is so long a time that there is a risk of including more than one storm, and so losing the characteristic outline and variation of intensity of the single splash. In the case of cyclonic rains, on the other hand, the day is often too short, and only takes account of a portion of the shower. There are many cases where a day's rain is entirely due to one thunderstorm, and many where the whole of a cyclonic storm is included within a day; but it more often happens that the onward movement of the cyclonic system requires account to be taken of the fall of two or three days.

Put broadly, we may say that heavy rains of both types are due to purely meteorological causes, and their elucidation must be sought in the configuration of the atmosphere as revealed by changes of pressure. Thunderstorm rains as a rule may be associated with squalls, cyclonic rains with storms, and the distribution of the rain, as has already been pointed out,[1] bears a definite relation to the track of the depression producing it.

As there are few really good records from self-recording rain gauges available, it is not possible to trace the travel of the rain-splash across the country, or to take account of its variation in size and form. In the case of the storm of November 11 and 12, 1901, when the cyclone track crossed Ireland and England from west to east, the smear of the rain splash of the 11th lay on the left of the track, and embraced nearly the whole of Ireland, the west and north of Wales, and ended with a nearly semicircular front in Yorkshire; while the smear of the rain-splash of the 12th began in the north-west of Ireland and extended to the east coast of Great Britain from Berwickshire to Lincolnshire. Had it been possible to ascertain the rainfall for each 12 hours the smear could, of course, be dissected into four overlapping splashes, the fronts of which

[1] "On the Unsymmetrical Distribution of Rainfall about the Path of a Barometric Depression." *Report*, British Association, 1904, p. 480, and *Symons's Meteorological Magazine*, **39** (1904), pp. 161-165.

would indicate to some extent the relation of the rain area to the advancing cyclone. When the splashes of the two days are united to give one smear, we find a broad band of rainfall exceeding an inch

FIG. 4.—Isochronic Map of Christmas Snowstorm, 1906.

stretching with a breadth of 200 miles across the country from coast to coast on the left of the track of the depression. There is no reason to suppose that such precipitation is less heavy over the sea than over the land.

The commencement of a snowstorm is more easily noted, and more likely to attract attention than that of a shower of rain, and in the case of the Christmas snowstorm of 1906 it was possible to prepare maps

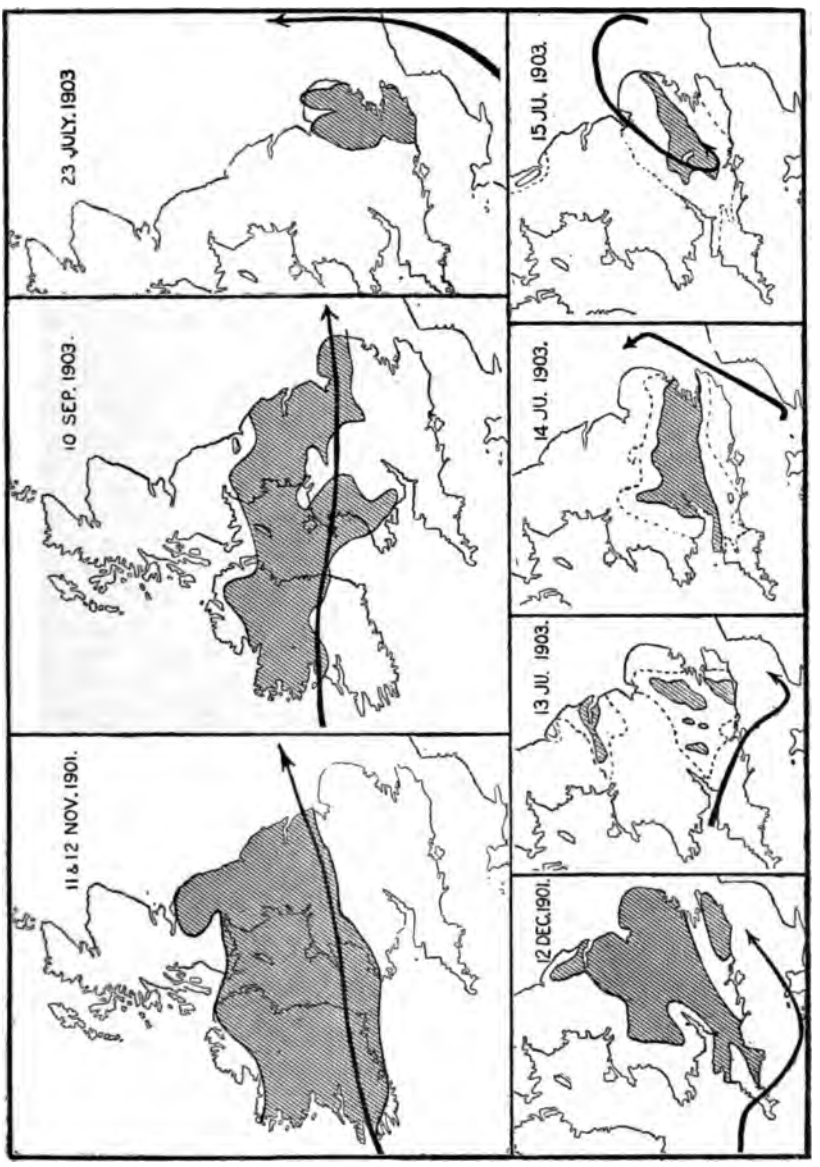

FIG. 5.—Specimens of Rain-Splashes.

showing isochronic lines as well as lines of equal depth of snow; and it is instructive to note that along the axis of greatest depth of snow the isochronic lines show a distinct bend forwards, indicating that the phase

of the storm was earliest along this belt which lay parallel to the track of the depression and on its left (Fig. 4).

A third example of the combination of the rain-splashes of individual days into a continuous smear—this time in the case of a small and shallow depression pursuing a looped path curving to the left, so that the area of heaviest rain was always on the inner side of the loop—is afforded by the memorable storm of June 13-15, 1903, when rain fell continuously for about 60 hours (Fig. 5, last three maps). On the 13th, when the depression was passing from the Bristol Channel past the Isle of Wight towards the coast of France, no rain fell on the Welsh mountains or on Dartmoor, or in the Lake District, while more then one inch was deposited in five areas in the Thames Valley, the largest being the farthest east on the comparatively low ground of the valleys of the Lee and the Medway. A splash of more than an inch also occurred in the valleys of the Don and Humber, the southern and northern wet areas being separated by a broad belt of country where less than half an inch was recorded. On the 14th, while the depression was nearly stationary in the Channel for many hours, and afterwards moved north-eastwards through the Strait of Dover, and thence parallel to the coast of East Anglia, the Welsh mountains, Dartmoor, and the whole north of England had again less than half an inch of rain, while a broad belt with more than an inch stretched straight across England from the estuary of the Severn to that of the Thames. Within this area four splashes of more than two inches occurred in line from west to east—one on Exmoor, two in the Thames Valley, and the largest and heaviest on the flat plain of Essex. On the 15th, when the track of the depression doubled on itself, and struck across England from the Wash south-westward to near Southampton Water, the splash of over one inch of rain lay parallel to the track some distance to the south of it. This again lay mainly in the Thames Valley, this time covering part of the Cotteswolds, the Marlborough Downs, and the Chilterns, but continuing in a narrower band through the eastern plain in Essex and Suffolk.

When the total rainfall of the three days is plotted on a map the smear of the rain, which in this case is doubled on itself, like the smear of a paint-brush worked to and fro, is seen to be very extensive for the area over 1 inch. A small area on Exmoor, and a very large area stretching east and west from the Bristol Channel to the coast of Suffolk and the Thames estuary, has a fall exceeding 2 inches; and, symmetrically arranged within this, a similar area reaching from Marlborough to the coast of Essex with more than 3 inches. Within the 3-inch belt four areas with more than 4 inches of rain are arranged in line from west to east. The high land of the Cotteswolds, Salisbury Plain, and the North Downs, come just within the area of more than 2 inches of rainfall. The area over 3 inches covers the Chiltern Hills, but shows a higher rainfall over the Oxford and the Essex plains, and the 4-inch patches are larger and heavier towards the east in the centre of the sweep of the depression's path. The relation of the amount of rainfall is thus with the atmospheric, and not the terrestrial, configuration.

The linear arrangement of rain-splashes in the map of a wet day suggests that there is some periodic increase and decrease of the intensity of rainfall in an advancing shower which is not generalised away by the consideration of 24 hours instead of the shower unit. One of the best

examples of this was presented on July 26, 1904, in a thunderstorm rain, a type more apt to show this characteristic than the cyclonic (Fig. 6).

These instances fairly illustrate the independence of surface relief shown in the intensity or distribution of great showers, and the close relation they bear to the passing minima of pressure.

Proceeding now to maps of the rainfall of a longer period such as a month, the total amount of which is often less, though usually more, than that of one of the wettest days, we find a curious divergence in character. Some months present a close resemblance in type to a wet day, or to a long cyclonic rain, the rain showing little regard to

FIG. 6.—Linear Arrangement of Rain-Splashes.

configuration of the ground; and this is not surprising, since it is no uncommon occurrence in summer for more than half of the rainfall of a month to fall in a thunderstorm on a single afternoon, or for this to occur at any time in a prolonged cyclonic rain. Thus the three days, June 13-15, determine the character of the rainfall map of June 1903 (Fig. 7).

On account of the great variation in the rainfall of a month, from nothing up to 6 or 10 or more inches, a very long period is necessary before average values can be secured which would not be considerably affected by the addition of a month of minimum or maximum rainfall. Thus if the average rainfall of one month for 30 years is 4·00 ins., the average for 31 years would be raised to 4·19 ins. if the rainfall of that month in the thirty-first year were 10·00 ins., and reduced to 3·87 ins.

if the rainfall were nothing, the difference to be expected being a range of 8 per cent. If the period were increased to 50 years the corresponding range would be only 5 per cent, and there are no records long enough

FIG. 7.—Map of Abnormal Monthly Rainfall.

to reduce the range appreciably below this figure. Hence it is practically impossible to compile an average map of monthly rainfall from which the disturbing influence of occasional very wet days would be eliminated.

As a rule, however, monthly maps of rainfall closely resemble each other in their general character, and if we disregard those amongst them

which bear the impress of one particularly wet day or spell, we cannot but be struck by the close relation which the amount of rainfall bears to the configuration of the land. The monthly rainfall map, in fact, is usually

FIG. 8.—Rainfall Map of Wettest Year.

a blurred impression of the hypsographical map; the region where high land prevails is that where high rainfall prevails, and the region of low land is the region of low rainfall, whether it be inland, or on the east coast, or on the west coast, while there is reason to believe that the general rainfall over the sea is less than that over the land.

The total rainfall of a year, when plotted, rarely shows much influence of individual wet spells, and a collection of annual rainfall maps does not present the diversity of feature found in a collection of monthly maps. The general resemblances are so great, and the diversities so unimportant that, speaking broadly, the run of the isohyetal lines is similar for the wettest or the driest year on record, for 1872 or 1887: though the general rainfall for the whole of the British Isles was 53·0 ins. in the former case, and only 30·5 ins. in the latter. An average map was prepared in 1903[1] for the period 1870-99, 30 years, based upon a selected list of 380 stations for which 30 continuous years of observations were available, and raised to 1050, by including somewhat shorter records reduced by calculation to the equivalent amounts for 30 years. The general rainfall of the British Isles deduced from this average map was 39·5 ins. The stations were as nearly equidistant as possible, and the isohyetal lines were drawn with reference to the figures solely on a map devoid of natural features, either land-relief or rivers. The result was to confirm a fact that had long been accepted as true, viz., that the rainfall was greatest in the neighbourhood of high land or diversified country, and least on low or level ground. In fact, the map of average rainfall presented a closer resemblance to the map of configuration than did any of the rainfall maps of individual years, and it might be said to be a less blurred impression than they. The isohyets were similar in their direction to the isohyets of individual years, though no year is a precise duplication of any other either as regards relative distribution or actual amount of rain, and in 1903, at least, the influence of an unprecedentedly wet period in a dry region is distinctly shown.

Much more detailed pieces of mapping have since been done of counties,[2] and groups of counties, and in every case the distribution of average rainfall for a period of 35 years has been found to show a detailed relation to the configuration of the land. The best instance of this is to be found in the map of Kent and Sussex, with portions of adjacent counties, where the influence of the hills and valleys of the south-east of England on the distribution of rainfall is beautifully shown. So close is the relation where observations are numerous, that it seems reasonable to cross bare places by following the lines of the configuration of the land. It must be remembered that in drawing a line through an irregular group of determining figures we have to be guided by probability, and that to rule a straight line between two points that are fairly fixed is in most cases to adopt the least probable route that could be imagined; the contour lines of level usually suggest the outline of the most probable route from point to point.

The present address is concerned with methods, not with results, but I can hardly touch on this part of the subject without pointing out that the side of a mass of high land which faces the prevailing wind shows a comparatively gentle and fairly uniform increase of rainfall with elevation, that the increase continues beyond the summit for a short distance, and is then succeeded by a much more rapid decrease of rainfall as the height diminishes. Such a relationship is to be expected only when the hills

[1] *Minutes of Proceedings, Inst. C.E.*, vol. **155** (1903-4), Part I.

[2] See the *Water Supply Memoirs* of the Geological Survey for the counties of Lincoln, Suffolk, York (East Riding), Bedford, Northampton, Kent, Sussex and Oxford.

are of moderate height; if it were a case of lofty mountains rising above the snow-line, the increase of precipitation would cease before the summit was reached. Slope probably plays an important part in determining how far beyond the crest the maximum precipitation occurs, and there is an immense amount of work to be done before the details of the relationship can be fully stated. While the relations that have been ascertained can be legitimately used as a guide in drawing isohyetal lines in desolate places, and may justify doubt and inquiry in instances of gross discrepancy, I do not think it is permissible for merely theoretical considerations to over-ride the evidence of a direct observation with which no fault can be found.

The average rainfall map may be taken as showing the effect of the interaction of the permanent configuration with the prevailing or average wind; but in individual years the wind may vary considerably both as regards mean direction and mean force, and the effect of these variations remain for future study.

Experience shows that when maps of individual years are constructed to show, not actual rainfall in inches, but difference from the average in percentages, certain tracts of country may be shown to be persistently above or below the average for several years at a time. The fact that the outlines of these tracts are often parallel to the usual paths of depressions suggests the idea that in certain years, perhaps in several successive years, the paths followed by the depressions bringing the heavy rain that falls irrespective of the form of the ground may be diverted to the north or the south of their usual course, or that more cyclones may follow one or another of the recognised tracks, and so create differences in the distribution of rainfall quite independent of such changes as many occur in its quantity. At present we are not in a position to investigate this part of the subject, because the average rainfall maps now in existence are not detailed enough; but when the series of complete annual maps of rainfall now being compiled at the expense of a rainfall observer is completed, it should be possible to combine them in some way so as to yield a map of average rainfall for more than forty years, the value of which ought to be very great.

In any individual year the total rainfall shows an unmistakable relation to configuration. The prevailing wind over the country is more or less South-westerly; but the fact that the wettest portion of the rain-splash in any squall or cyclone which produces a very wet day lies wholly to the left of the track, shows that in storms pursuing the more usual tracks from a westerly to an easterly point the maximum precipitation takes place with an Easterly and not with a Westerly wind. We have seen, however, that the splashes, or, to be more precise, the smears, of heavy rain show no apparent relation with configuration, but fall equally on highland and lowland, hill-brow or valley floor. It would, therefore, appear to be necessarily true that the elimination of all such heavy meteorological rains would leave the remaining geographical rains much more intimately associated with the configuration than is the total rainfall of any year.

The attempt to differentiate between the two classes of rainfall is extremely difficult because of the enormous labour of analysing a sufficiently large number of perfect daily records to yield a map detailed enough for the necessary comparison. An attempt has, however, been made

to separate the rainfall into the two types. For this purpose England and Wales were alone considered, and 300 stations with perfect daily records were selected to give as uniform a distribution over the surface as possible.

One map was prepared from the 300 points showing the total annual rainfall for 1906, a year which on the whole closely approached the average. The question, then, was to decide what rainfalls to sift out as probably of meteorological origin, and it seemed hopeless to attempt to sort out all days of cyclonic storms and squalls and deal with the stations within the storm area on each occasion. At first the maximum fall (*i.e.* the rainfall for the wettest day of the year) was taken out, and the change on this occasion was so slight that all other days were taken on which the rainfall reached or exceeded 4·5 per cent of the annual total, that being the average percentage of the maximum fall. A map was constructed from the 300 points showing the total fall, less the maximum fall, and all falls exceeding 4·5 per cent of the average, and this was compared with the map of total annual rainfall. It was found that the 300 points were not sufficient to allow the isohyets to be drawn with sufficient precision to allow of a close comparison, but looking at them in their broad features only, and disregarding details as far as possible, one could see a perfectly clear smoothing and mellowing of the outlines. The map of total rainfall, minus heavy falls, was more like the average map than was the map of total rainfall from which it was derived, the differences being most easily seen in the Eastern Division of the country, where the effect of the low hill ranges on rainfall became more prominent. In the Western Division there was comparatively little change, the isohyets in both maps showing an equally close correspondence to the configuration.

A further step was then taken, and all daily falls which individually exceeded 1 per cent of the annual total rainfall at the station in question were excluded. The map expressing the distribution of this doubly reduced rainfall was still in close accord with the configuration in the Western Division, but in the Eastern Division the isohyets were broken up and confused, suggesting that the process had been carried too far.

Having done so much I thought that it would be worth while to attempt a little more by applying the same process to the records of a year which was widely different from the average, and 1903 was selected for this purpose, as it was one of the four wettest years of the last hundred, and it contained a number of notable heavy falls. The same limits of reduction were adopted. This time the withdrawal of the day of maximum fall and all days with more than 4·5 per cent of the average fall produced very little change, as the total rainfall was so unusual that even a large daily fall formed but a low percentage of it. The second reduction by withdrawing all days with more than 1 per cent of the annual rainfall produced a considerable accentuation of the relation of rainfall to the surface relief of the Eastern Division of the country, and evidently came nearer to securing the elimination of the meteorological rains; but the result was not striking.

To complete the test of the method a very dry year, such as 1887, should have been treated in the same way; but time could not be found for doing this. The result of the attempts that have been made

goes to show that the method is a promising one if a sufficient number of records can be secured to give definiteness in drawing the isohyets, and if one can ascertain the proper amounts to be deducted in order to weed out the meteorological rains and leave the configurational rains alone. An attempt may be made at some future time to apply the method to a smaller area on a larger scale. Meanwhile enough has been done to show that the elimination of the heavier falls of rain leaves the residual amount in closer harmony with the surface features of the land, and that even without modification the rainfall of every year corresponds so closely with the configuration of the country as to prove that a relationship of cause and effect exists between them, and this relationship is undoubtedly what is termed in geography a control of rainfall distribution by the land.

For many practical purposes it is important to ascertain the total

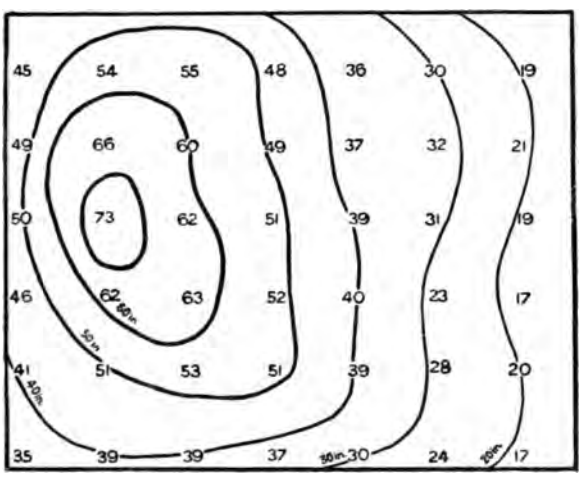

FIG. 9.—Isohyets for Regular Distribution of Stations.

volume of water which falls as rain on particular areas, and when the area is large, a river basin for example, the only really satisfactory way is by the use of a rainfall map. The problem of finding the general rainfall of an area on which there are numerous records appears to most people at first sight to be solved by the simple process of taking the mean of all the records which exist. A little thought, however, is sufficient to show that it is only in very rare circumstances that this is the best course to follow. It is only when the stations are uniformly distributed over the whole area, and sufficiently numerous to represent all the different intensities of rainfall proportionally, that a mean of all the figures can give the true general rainfall. When there is little difference between the rainfall in different parts of the area a comparatively small number of stations will suffice to give a representative mean value; but the greater the diversity is, the greater is the number of stations required for the purpose. When, as in this country, the rainfall records are not taken at selected points chosen as to position and number, but here and there for the most part at the hazard

of the grouping of the homes of the one ten-thousandth of the population interested enough to become observers, stations are not sprinkled uniformly over the surface, but clustered together in favoured residential districts and totally lacking in many large areas. The mean of such irregularly distributed stations can only represent the general rainfall by accident. Thus if in a county there are 30 rain gauges in a hilly district of 400 square miles, and 5 in a stretch of level fenland extending for 1000 square miles, the mean of the 35 records would give far too high a figure for the rainfall of the county. Even one phenomenally wet station may greatly disturb and misrepresent the rainfall of the county; for example, if the records of the three rain gauges at The Stye are included amongst 50 stations in Cumberland, the mean for the whole county would be raised several inches above the true general fall. It is difficult,—indeed, I have sometimes found it impossible,—to

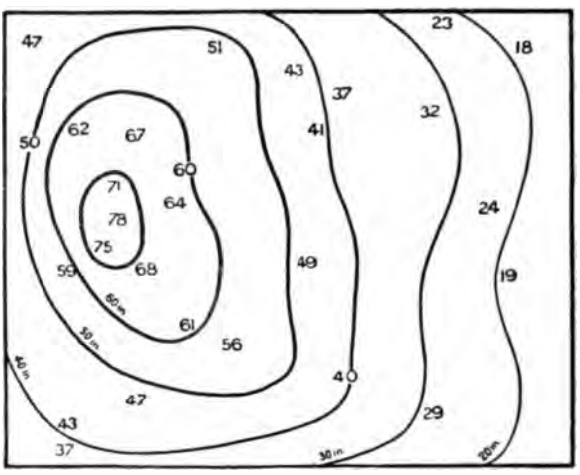

FIG. 10.—Isohyets for Irregular Distribution of Stations.

convince people who are intelligent in most matters, that by omitting half the records of rainfall one could in certain cases obtain from the mean of the rest a far closer approximation to the general rainfall than by taking the mean of all. Dealing with numerals alone in a tabular form they fail to see that space and grouping have to be considered as well as number, and that in taking an arithmetical mean as expressing the general value they are making the great and unwarranted assumption that the distribution of the stations is uniform and representative.

When all the data are placed upon a rainfall map the drawing of isohyetal lines involves some assumptions also, as we have seen; but these are of a smaller and more reasonable kind. From an isohyetal map the general rainfall can be obtained by various methods. One of these, and perhaps the most accurate, is to construct a number of sections along parallel lines at close intervals across the map, the co-ordinates being distance and depth of rain, then measuring the area of each section, adding all the areas together, and dividing by the total length of the sections to give the general rainfall.

A simpler method is to measure the area between consecutive isohyetal lines upon the map, multiply the area by the general rainfall of the zone, add all the resulting figures together, and divide by the total area. For convenience I measure the areas in square miles to the third decimal place, and the rainfall in inches to the second decimal place, the resulting volume of rain being given in the conveniently large units of the square-mile inch which is equal to 14,480,000 gallons. The only serious risk of error in this method lies in estimating the general rainfall of the zones, and this is much less than might appear at first. Where the isohyets are numerous and equally spaced it is safe to take the general rainfall of the zone, between say 30 and 35 inches, as the mean of the two limiting values, *i.e.* at 32·5 inches. Where, however, the isohyets are becoming successively nearer, or successively farther apart, from the lower to the higher value, it is necessary to allow in the former a lower, and in the latter a higher value than the mean. In practice the actual figures usually serve to show whether the mean value has to be diminished or augmented, and by what amount; and even if this rectification is not made the error in most instances is not a great one. All calculations of the volume of rainfall are subject to the limits of accuracy of the individual observations, and it is taking a very favourable view to assign one-tenth of an inch as the smallest difference which has any significance in the figure for annual rainfall.

It happens that rainfall is not only the most difficult of all the meteorological distributions to map accurately, it is also that one which is of the greatest practical importance; for by rain the rivers are fed, and the rivers both water and drain the land. The value to agriculture of a knowledge of rainfall and its seasonal incidence is great, but not so great as the value to other interests. Every year makes clearer the vast national importance of accurate knowledge of the rainfall of a country, for the problem of the rivers is becoming acute. The growing populations of the great towns are tapping the upper streams and diverting the water from its natural channels, and at the same time they are polluting the lower courses with the waste of the factories and the streets. Toll is taken all along the banks of industrial streams of water for raising steam and carrying on the multitudinous processes of manufacture. There is sometimes anxiety as to whether the waterways can be kept sufficiently supplied to float the water-borne traffic, or to fight the silting action of the tides in the estuaries, and there is growing alarm as to the possibility of fish traversing the depleted and polluted streams to reach their spawning beds.

Of recent years the value of the water-power which may be generated in the lonely and lofty places amongst the western heights of Great Britain, where the rainfall is large and unfailing, has been recognised; and chemical works for the production in electric furnaces of what a few years ago were rare substances are becoming familiar features in Wales and the Highlands. In Ireland, too, the rainfall is an unrecognised source of wealth which as yet has not been drawn upon to any appreciable extent. The increasing strenuousness of the struggle for the possession of large water-supplies is producing in England, and especially in Wales, a great amount of local jealousy and strife, for the boundaries of parishes and counties coincide but rarely with water-partings, and the argument

has been brought forward again and again that the rainfall of one county should not be diverted for the use of the inhabitants of another. The feeling is intensified when the boundary to be crossed is that of a historical division of national importance, like the boundary between England and Wales; but I think that the map-study of rainfall can do something to suggest the lines on which such disputes should be settled. A great statesman once recommended the study of large-scale maps for the solution of political difficulties, and no doubt matters of detail are often important enough to require such aid; but in order to grasp the true bearings of large subjects in their entirety we must use a small-scale map, or we fail to get a comprehensive view. We have seen that although the exceptional deluges of a thunderstorm or a great depression fall with equal and impartial heaviness on the hills of the west or the flat plains of the east, the common every-day rains are precipitated on the high lands and in the mountain valleys, which cross the track of the prevailing wind, in much greater abundance than on level and low stretches of country. Most of the rain is borne to our islands from the Atlantic, and, when it comes torrentially, it is a thing of the air alone and no boundary checks it; but the largest annual falls come down on and near the water-sheds, because there the land produces its maximum influence as a rain-compeller. In our youth we were taught that mountains attract rain, but that is rather a misuse of words unless we stretch the word "attract" so far that we could speak of a body of bandits attracting plunder. If the high ground of Wales, the Lake District, and the Pennines were not there to obstruct and plunder the Westerly winds the lower heights of eastern England would receive a much greater annual rainfall than they do.

From the high ground the rivers seek the plains, carrying off the excess of rainfall into the less liberally watered districts. The Dee, the Severn, the Wye, and the Usk restore to England part of the rains which the Welsh mountains have abstracted as the air passed over them. The high rainfall of the whole Pennine district, sometimes by circuitous routes across the comparatively dry plains of the east, swells the volume of fresh water that pours into the Humber. The Thames itself receives the comparatively high rains of the Cotteswolds, the Chilterns, and the Downs, and forwards the water slowly through less and less rainy districts until it reaches the sea in the driest part of England. I think that a far stronger argument can be drawn from this consideration of physical geography in favour of supplying the great towns of the east from the large precipitation of the west, than can be drawn in the opposite sense from the artificial divisions of political geography. It seems to me that care for the water-supply of the country, coming as it does from the air that knows no bounds across the land, is by no means a parochial, but in the fullest sense a national matter, and should be dealt with in the interests of the nation as a whole—the units of subdivision when such are required being the natural units of river basins.

This Society owes something to the nation in giving expression to the possible practical applications of the science we pursue, and I am sure that if the public were once thoroughly aroused to the wide importance of our studies as they bear on every-day life, the general proceedings of the Society would be followed with a keener interest and the number of Fellows would greatly increase.

FORMATION OF SNOW ROLLERS.

By CHARLES BROWETT.

(Communicated by the Director of the Meteorological Office.)

[Read February 19, 1908.]

At Ryton-on-Dunsmore, near Coventry, on the afternoon and evening of January 29, 1907, there were several storms of fine snow, which amounted to a depth of about 1½ in. The snow fell very evenly and without drifting.

The next morning at 8 a.m. I noticed that the snow on the lawn to the east of the house was heaped up as though some one had run with a spade in front of him. On going out I found myself face to face with a very curious phenomenon. The snow was cleared away to the bare grass (except for slight bars of snow across) in tadpole-like markings, whose tails all pointed to the direction from whence the wind had been blowing all night, viz. North-north-west, and at whose heads was heaped up the snow that had been on the bared grass, all neatly turned over in a roll. On looking about on the other lawns I found only a few of these markings, and on the field to the north none at all; but on the drive and grass in front of the north side of the house I found markings in the opposite direction, but with little snow actually curled up, although the grass was bared in the vertebræ-like spots before mentioned. It was quite evident that these were caused by the deflection from the side of the house of whatever had caused the similar markings on the other side.

On driving into Coventry (4 miles) I noticed in many fields similar markings to the first mentioned; but the field that had most in was one sloping slightly from the north-west to the river Sowe. But oddly enough none were on the other side of the river, where the ground rose facing the wind. On inquiry I found several odd ones had been formed on lawns and fields to the north of Coventry. In every case the snow was as clean cut as with a knife. The main sheet of snow was not drifted in any way.

The following are the exact details as far as they could be obtained :—

Greatest length of any one marking 30 ft., average 20 ft., smallest about 6 ft. Width of grass cleared at the start, which was gradual, not less than 3 ins. to from 12 to 17 ins. at the widest part. Wind North-north-west. Force gusty up to about 25 miles per hour. The thermograph 5 ft. above ground recorded between 32° and 34° during the night. The surface of the snow was perfectly flat; no tufts of grass or any projections were in any way connected with the formations. Fine snow fell on and off all the previous afternoon. I do not think any snow fell after dark, but these markings were cut through all there was on the ground between 6 p.m. on January 29 and 6 a.m. on January 30, when it was fine. They were not made during any fall of snow. The edges were as sharp as if cut with a knife. The ridges across the figures were about a quarter of an inch deep, and were left about every 6 ins. I counted 13 in 7 ft. On either side of the heaped-up roll of snow the

grass was always slightly cleared, as though the wind, being unable to push the snow farther, had divided and gone by on either side.

On the south side of the house many very strange forms had been cut on the lawns among the trees and shrubs; the most interesting and the best marked is shown in Fig 1. It was secured in the following way, as a photograph, even taken from the top of the house, was subject to perspective. I cut with a large knife the sharp edge of the snow down to the turf and put a number of pegs in this nick so that when the snow had gone very accurate particulars could be taken. To do this I marked out on the turf round it a square of 8 ft., its sides being north,

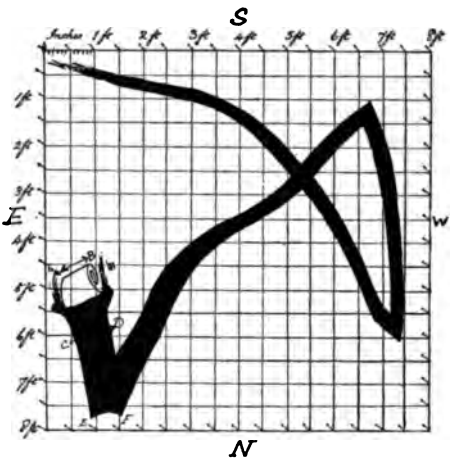

FIG. 1.

south, east, and west, and put a nail in every 6 ins. all round. Fine cotton was then passed backwards and forwards, and from its intersecting points the figure, as shown, was easily and accurately obtained. The distance across AB was always a good deal less than that at CD, where the snow at AB would have come from if simply rolled back. This showed a pushing-along action as well as a rolling one. If the roll could have been undone, it would not have reached more than a quarter of the distance along the bared grass. The figures on this side of the house were formed in all directions, the trees and shrubs causing an almost complete reversal of the direction of the main wind current. The curve at EF was very marked.

[The following extracts giving descriptions of similar phenomena observed elsewhere will throw further light upon the formation of "snow rollers."—EDITORS.]

From *Handy Book of Meteorology.* By ALEXANDER BUCHAN. Second Edition, 1868, pp. 202-3.

On the 5th March 1862, about 9 p.m., the Rev. Dr. Charles Clouston, Sandwick, Orkney, observed the snow which was then covering the ground to be rolled up by the wind into masses increasing in size as they moved before it, which were

blown backwards and forwards in the eddy-wind of the house. The same phenomenon had occurred in February 1847, and was then described by him in the following terms: "On examination, the masses were all found to be cylindrical, like hollow fluted rollers, or ladies' swan-down muffs, of which the smaller ones reminded me, from their lightness and purity, but most of them were of much greater dimensions and weight than any lady would choose to carry, the largest measured being 3½ ft. long and 7 ft. in circumference. The weight, however, was not so great as might have been expected from the bulk; so loose was the texture, that one 3 ft. long and 6½ ft. in circumference was found, on being weighed, to be only 64 lbs.; the centre was not quite hollow, but in all there was a deep conical cavity at each end, and in many there was a small opening through which one could see, and by placing the head in this cavity in the bright sun, the concentric structure of the cylinder was quite apparent. They might occupy 400 acres, and I counted 133 cylinders in one acre. A combination of favourable circumstances is required for their formation —viz. a recent fall of loose snow-flakes in calm weather, as took place on the day previous; a temperature near the freezing point, so as to give adhesion to the snow, while it is not so warm as to thaw it; a good breeze of wind to spring up when the other circumstances are favourable to their formation."

From *Nature*, vol. 27, 1883, p. 483.

A Remarkable Phenomenon—Natural Snowballs.

Mr. Samuel Hart, Trinity College, Hartford, Conn., U.S.A., gives the following account of natural snowballs, which he furnished to the *Courant* newspaper, February 22, 1883:—

On Tuesday evening a light but damp snow fell upon the crust that had formed over the snow of Sunday's storm; and the South wind, which arose at a later hour, produced an unusual phenomenon. Wednesday morning the college campus, the park, and vacant lots everywhere hereabouts were seen to be strewn with natural snowballs, some of them resembling spheres with diameters of from 1 to 9 ins. or more, and others looking very much like rolls of light cotton batting, having a cylindrical shape, but in nearly every case with a conical depression at each end reaching nearly or quite to the middle. It was easy to see how the balls had been formed, as it is easy to see how boys roll up snow for their forts. The wind had in each case started a small pellet of moist snow, and it had rolled along until it grew so large that the wind could move it no farther. The ball not only increased in diameter as it rolled, but also grew gradually in length as a little more of the snow stuck to it on each side, as thus the snow was formed in the peculiar way described—that of a cylinder with a hollow at each end, as if a long isosceles triangle were rolled up beginning at its vertex. The largest of the cylinders measured on the college campus had a diameter of 12 ins. and a length of 18 ins.; while others in the fields in the neighbourhood seemed much larger. The path of the balls could in many cases be readily traced for a distance of 25 or 30 ft. The snow, it should be added, was not at all closely packed, but lay together very lightly and yielded to the slightest touch, so that it was impossible to move a ball without breaking it.

Observers in other parts of the city report that some balls were seen of the size of a barrel which left tracks behind them for more than 60 ft. From East Hartford it is reported that they studded the fields thickly, especially in places where the wind had a long range, and were of every size to that of a half-bushel or larger. Similar balls were seen yesterday morning in many places from the Sound north to Massachusetts. All along the line of the Valley Railroad they

appeared on every rod of ground, and at some places they had left tracks showing that the wind had blown them in every direction, even in some cases uphill.

This interesting phenomenon, though quite unusual, has been noticed before in different places in this country and elsewhere, the most striking instance being one which was observed in New Jersey in 1808; this was in the daytime, when the whole process could be watched. On this occasion some of the masses of snow which were rolled up by the wind attained a diameter of 3 ft. They appear to have been seen over an area of only some four hundred acres, whereas the snowballs yesterday were spread thickly over many square miles.

From *Nature*, vol. 27, 1883, p. 507.

Snow Rollers.

The phenomenon described in *Nature*, vol. 27, p. 483, under the title of "Natural Snowballs," is known to British meteorologists under that of snow rollers, and as the latter agrees more closely with the phenomenon, I venture to plead for its adoption.

I believe that the first person who carefully examined their formation was that excellent and venerable observer, the Rev. Dr. Clouston of Sandwick Manse, Orkney, and I am under the impression that he published a description of their formation in an early number of the *Philosophical Magazine*. He has observed them on the lawn at Sandwick more than once, and has always noticed the hollowness at the ends; in fact, he described them to me as resembling ladies' white muffs.

I remember only one instance of their being reported in England, namely in the following letter from the late Admiral Sir F. W. Grey, which appeared in the *Meteorological Magazine* for May 1876. G. J. Symons.

62 Camden Square, N.W.

Sir—The snowstorm of Thursday night [April 13, 1876] was marked by one circumstance which I have never witnessed before, though it may not be uncommon. It was this:—

On Friday morning I observed that for a considerable distance, and following a regular line, the lawn, to leeward of the house, was strewed with masses of snow-like boulders, varying from the size of a snowball to a cubic foot at least, and as the snow melted, a track either straight or curved led up to the large ones, following apparently the direction of the wind. I had observed before dusk that the eddies of the wind and the swirls of snow were very marked, and I have since heard from a friend, who observed the same thing, that he saw the snow rolled along by the wind and forming masses such as I have described.

As I have said, I know not whether this has been observed in other cases, and perhaps it may interest you to have this account of it.—Yours faithfully,

F. Wm. Grey.

Lynwood, Sunningdale, Staines, *April* 16 [1876].

From *Symons's Monthly Meteorological Magazine*, vol. 20, 1885, p. 7.

Snow Rollers

Sir—On the 13th inst. a large number of "snow rollers" were formed here, and as I see from a letter in *Nature*, vol. 27, p. 507, that the

phenomenon has not often been noticed in England, you may think the circumstance worth recording. I first noticed a few on the 12th, the snow being about 0·5 in. deep and a strong North wind blowing; more snow fell in the night and next morning, to a depth of more than 3 ins., and on going out in the afternoon I found all the open fields strewn with a number of rollers, varying in size from that of a hen's egg to cylinders about 9 ins. in diameter, and about the same length. I did not see any in course of formation, but there were tracks in the snow leading up to them on the windward side. The snow was rather moist, temperature being about freezing point, and lay light, 3 ins. of snow yielding about 0·11 in. of water at 9 a.m. A few of the larger ones were left next day, but the greater part had been blown away.

H. MELLISH.

HODSOCK PRIORY, WORKSOP, *January* 15, 1885.

From the *U.S. Monthly Weather Review*, 1906, vol. 34, pp. 325-326.

SNOW ROLLERS. By WILSON A. BENTLEY, Jericho, Vt.

During the night of January 18, 1906, there occurred at and in the vicinity of Jericho, Vt., the very interesting and somewhat rare phenomenon of the formation by wind action of vast numbers of snowballs, or snow "rolls" or "rollers." A brief account of them, and of the weather conditions that prevailed before and while they were being formed, may possibly be of interest to the readers of the *Weather Review*.

About five inches of very light, fluffy snow fell during the twenty-four hours immediately preceding the phenomenon. During this time the temperature ranged from 14° to 22° F. But during the night of the 18th, when the snow rolls were formed, the temperature slowly rose from 24° to 34°, and the lower wind shifted from Westerly to Southerly points, and blew at times in a very strong but intermittent and peculiar gust-like manner. The snow rolls were formed during the latter part of the night, after the rise to 34° was accomplished. This rise in temperature operated to cause a slight superficial melting of the upper layers of the snow, and to make it slightly damp, so that the individual snow crystals tended to cling to one another.

So far as the writer was able to observe, and to learn from others in adjoining towns, the phenomenon occurred only over a quite limited and narrow strip of foot-hill country perhaps one mile wide, lying alongside and parallel to, but at a little distance from, the western side of the Green Mountains. The winds that produced the phenomenon blew across the valleys and foot-hills rather than parallel to their greater length. The topography of the region in question is such as to cause the winds that reach the valleys, or at least some of them, to flow or pour downward into them in descending order from foot-hills of considerable height.

In many cases the gusts of wind evidently had a strong descending motion, such as just described, for they actually scooped up considerable masses of the light, damp, fluffy snow and formed it into ridges or hollow snow arches, and rolled many of these up into snow rolls of various sizes.

The forms and structures of the snow rolls were such as to indicate that, at least in many cases, the wind that scooped up the fluffy snow masses into ridges or open arches got in behind such ridges and arches (which may be termed "cores") and blew them over upon themselves or upon the snow directly in front and to the leeward of them, thereby imparting both rotary and forward motions to the snow core ridges or arches, blowing and rolling them along in this manner for some distance. Fresh layers of damp surface

snow collected upon them as they rolled along upon the surface of the snow, and operated rapidly to increase their size and specific gravity. Eventually the rolls became so large and heavy that the winds were unable to roll them farther and they came to rest. Variations in exposure to winds and surface topography operated to cause some rolls to be blown along much farther than were others, hence some became of much greater size and weight than others. The individual snow rolls varied in size one with another, from tiny rolls but a few inches in diameter, to huge ones 18 by 24 ins. in size. In most cases the diameters of the rolls were much less than were their lengths.

Perhaps the most interesting rolls thus scooped up and modelled by wind action were those whose "cores" were of an open, hollow character. Such

FIG. 2.—Snow Rollers at Jericho, Vt.

came into existence in the form of hollow snow arches, as previously described, and were so substantial, or were rolled along so gently by the winds, that their hollow cores were preserved intact, *i.e.* were not filled in as a result of collapse or of their rotary experiences.

Unfortunately the day following the formation of the snow rolls was a dark cloudy day, unfavourable for photographic work, hence our original photographs of the snow rolls failed to show them with sufficient plainness, and it became necessary to increase their sharpness by recopying so as to produce extreme contrast effects. This explains why the trees, etc., show up so very darkly in these photographic prints (Figs. 2 and 3).

The wind came from the right-hand side of these photographs. They show the paths of some of the rollers, and their beginnings on the right-hand side. The accumulation of snow occurring on the right-hand, or windward, side of each roller was, I am certain, not blown there from a distance by the wind, but is, in each case, a partly detached layer of snow, that adhered to,

and was partly lifted up by the roll, while that was revolving, but that settled back to earth at a later time, owing to the continuation of the process of partial melting that was going on at a temperature of 34° to 36°. In case the roller had undergone another revolution such windward layer would doubtless have gone with it and been incorporated within the mass. Many of the rollers formed on a practically level surface, and some were actually rolled up a slight incline.

FIG. 3.—Snow Rollers at Jericho, Vt.

From the *U.S. Monthly Weather Review*, 1906, vol. 34, p. 326.

SNOW ROLLERS AT MOUNT PLEASANT, MICH. By Prof. R. D. CALKINS.

On the evening of January 17 [1906], the wind at Mount Pleasant, Mich., was North-east, and a light flaky snow was falling. During the night the wind backed through North and North-west to the South-west. In the morning we found that, at the north-west corner of the Normal School Building, snowballs or snow rolls to the number of fifty or seventy-five had been formed. They varied in size from 3 ins. in diameter to 12 ins. They were rolls of snow rather than snowballs, for most of them had square ends. They were spiral in structure when viewed from the end. Behind each roll was a path where the snow had been taken up, and the depth of snow removed from this path corresponded very closely to the thickness of the layers forming the roll. These paths became narrower as the corner of the building was approached, where they all disappeared. The rolls were very light, and would hardly hold together sufficiently to preserve their shape when lifted. Some boys from the country on the same morning reported similar balls 2 ft. in diameter. The wind had a long unobstructed sweep from the south-west. There were no tracks of children about

the balls, and there can be no doubt that they were wind-formed. Can you give me any more information concerning the origin of such balls or rolls? Just why and how do they start?

Note.—The initial step in the formation of snow rolls seems not yet to have been observed. They appear generally to be formed at night-time, or in the very early morning, and the diagram by Professor Calkins suggests that they are formed by or among the eddies in the strong wind at the corner of a building or other obstacle.

We note that in the *Meteorologische Zeitschrift*, May 1895, p. 198, Prof. K. R. Koch, of Stuttgart, mentions three ways in which snow becomes hardened after it has fallen :—

1. A warm snowfall is followed by cold West winds that favour compression, the wind in descending gusts forcing or pressing it into a hard solid mass.

2. Hard surfaces are formed by melting and freezing, and become hard enough to support the mountain climbers in the Alps and Black Forest.

3. In March and April, in the mountains, before thawing weather begins, the insolation is powerful, and snow crystals exposed in the sunshine are evaporated and the vapour is actually recrystallised ; thus very large crystals are formed, and the layers of snow become quite solid ; it is not impossible that large nuclei may thus be formed.—C. A.

From the *U.S. Monthly Weather Review*, 1907, vol. 35, pp. 70-71.

Snow Rollers at Canton, N.Y. By M. L. Fuller.

I send a few notes relative to the formation of snow rollers in the village of Canton on February 19, 1907.

The conditions attending the formation of the rollers were as follows :—

Upon a dry and evenly distributed snow covering of 4 ins. depth there fell late in the forenoon of the 19th a half inch or more of fine, dry snow. After 1 p.m. the falling snowflakes were of greater size, becoming large, moist, and feathery after 3.25 p.m. and continuing to 4.25, by which time a total of about one inch had fallen. Light snow with about one-tenth inch of dry sleet occurred from 4.25 to 6.55 p.m.

The temperature, from 10° F. at the 8 a.m. observation, increased to 17° by 3.15 p.m. ; then rose suddenly to 31° at 3.30, and slowly to 34° by shortly after 6 p.m., from which maximum it fell to 17° by 7.15 p.m.

This abrupt rise of temperature and brief thaw accompanied a South-west wind with a velocity of 30 to 40 miles per hour that burst suddenly upon this locality at 3.25 p.m., displacing the North-easterly winds of 4 to 12 miles of the morning and mid-day, which had continued practically up to that hour.

Though the formation of the rollers was not witnessed, so far as ascertained, it is known to have occurred between 5 and 6 p.m. Small rollers were found next morning in a variety of locations. The largest had been developed on a sloping lawn where the strong wind, striking the exposed side of a large cottage, had swept downward and away, rolling the snow downhill. Here the largest attained diameters and lengths of 10 to 12 ins. In structure they closely resembled rolls of cotton batting, but the centres were almost invariably shorter than the outer layers. The layers were plainly marked, and varied somewhat in thickness, averaging probably three-fourths of an inch or more, and being usually thinner near the axis. In occasional instances the centres were very short or almost wanting, and the rolls, although firm enough next morning to be handled, were much lighter than snowballs of the same size when rolled by

hand, thus indicating but slight packing of the snow in the wind rollers (Fig. 4).

From the conditions observed in this instance, it would appear that the flakes of a light fluffy layer of surface snow are made adhesive by a sudden rise in air temperature, while the under snow still remains cold and dry, and the particles of damp surface snow are enabled to adhere to each other, but not to the dry under snow. A strong wind may then push over little prominences or projections of the surface snow, and start them rolling, when of course they will continue to travel and grow until the resistances overcome the propelling power of the wind.

Miss Ione A. Jillson subsequently reported having once witnessed the formation of snow rollers, and at the suggestion of the writer contributes the

FIG. 4.—Snow Rollers at Canton, N.Y., February 20, 1907.

following account. As its author appears to be habitually careful and painstaking in both observation and statement, the description is thought to be of value:—

"During the winter of 1895 I watched the formation and progress of so-called snow rollers. The temperature was probably a trifle above the freezing point, following a snow-storm characterised by very large light flakes. For the most part the wind seemed to sweep downward and get under a slightly projecting mass of snow, and set it in motion. As the roll grew in size the speed, at first very rapid, slackened, until the mass became too compact and heavy to be moved farther. Sometimes a triangular-shaped "card" of snow, often 3 or 4 ins. across the base, would rise and fall several times before the wind gained sufficient purchase to turn the point over and start the roller. This card looked very much like the corner of a piece of paper as it rises and falls with the wind

just before it is blown away. The snow seemed to be of an unusual consistency, rendering it tough and flexible.

"These rollers were observed at Edenton, St. Lawrence County, N.Y."

DISCUSSION.

Mr. H. MELLISH remarked that he had observed the phenomena several times at his own place. Last winter he had seen it on three occasions, one of which was on the morning referred to in Mr. Browett's paper, although he lived seventy miles from Coventry where Mr. Browett had observed the snow-rollers. The other two occasions were in connection with the Christmas snowstorms. Snow fell on Christmas night 1906, and on the following night snow-rollers were formed in great abundance. These were first noticed in the moonlight, and in the morning there were a great many of them, the largest being 16 inches in diameter by about 1 foot long, and with hollow ends and short centre; the centre in some had altogether disappeared. Snow fell again that evening, and on the morning of the 28th more rollers were found, also on January 29. As regards the conditions, nearly all the accounts referred to the light fluffy snow falling, followed by a temperature just above freezing point. He had looked at the thermograph last year on each of these three occasions, and on each the minimum temperature occurred in the early evening, being followed by a considerable rise before midnight. On January 26 the temperature fell to 17° soon after sunset, and rose later in the evening to 33°. The following night it fell to 24° (between 5 and 6 p.m.) and rose afterwards to 34°. On the third occasion it fell to 30°·4, which was not so low as previously, and then rose to 35°. It therefore appeared that a necessary condition for the formation of these snow rollers was a temperature slightly above freezing following a rather cold one.

Mr. J. E. CLARK remarked that one interesting point about these snow rollers was, their extreme lightness when compared with similar rolls made by hand. He thought that the wind lifting the rolls would account for this. It would have been interesting to see whether the weight of the rolls on the other side of the slope would have been greater. Possibly the larger number of rolls on the slope from the wind indicated that the wind had got right under them. The wind must have been sufficient to raise the balls as they rolled. The remarkable zig-zag showed the force of the wind, as it no doubt meant that the rolls were reversed endways. If that cylinder were examined it would be found, probably, to have three separate axes.

Mr. C. BROWETT, in reply, thanked those present for their kind appreciation of his paper. As regards the description of the snow rollers he quite agreed with the last speaker. It was a strange thing that none of them should have been on the field facing the wind, while a great number were on the field inclining towards the wind. He also remarked that the most noticeable characteristic of the little vortices that undoubtedly caused the snow rollers, was their persistency independently of the main wind current, and that they were not dissipated by striking against the house, but rebounded directly against the main wind current, though they were not then strong enough to produce actual rollers.

THE PRESIDENT, in thanking Mr. Browett for his very interesting account, said that the ingeniously constructed plan of the snow roller was one of the neatest examples of coping with an unexpected meteorological phenomenon he had seen.

COMPARISON OF SHIPS' BAROMETER READINGS WITH THOSE DEDUCED FROM LAND OBSERVATIONS; WITH NOTES ON THE EFFECT OF OSCILLATORY MOTION ON BAROMETER READINGS.

By ERNEST GOLD, M.A., F.R.Met.Soc.

(Communicated by the Director of the Meteorological Office.)

[Read February 19, 1908.]

Preliminary Note by Dr. Shaw.

In plotting, upon the working charts of the Meteorological Office, the observations received from the ships of H.M. Navy by wireless telegraphy within the past year, discrepancies have been noticed on various occasions between the pressure readings and those which would have been anticipated from the distribution of pressure over the adjacent land areas. In not a few instances, to have drawn isobars over the sea in strict accordance with the observations thereon would have introduced such contortions into the generally smooth run of the curves that the alternative of disregarding the observations seemed to offer a course more in accordance with official experience of nature. Yet in many cases, after being referred to the ship for confirmation or correction, the observations were returned duly confirmed. It had also come to my knowledge that the discrepancies between ships' readings of pressure in the Indian Ocean and neighbouring land readings were the occasion of some difficulty in the interpretation of the results. At the same time, having regard to the investigations of Sir G. Stokes upon ships' barometers, errors exceeding the hundredth of an inch could not be regarded as accounted for by instrumental difficulties. In order to obtain further information I utilised the occasion of Mr. Gold's presence at the Office for some days at the commencement of this year to obtain a comparison between the barometer readings of a number of ships of the Mercantile Marine, which keep a four-hourly log for the Meteorological Office, and the simultaneous values of the pressure as deduced from the readings of barometers ashore. Mr. Gold has made the question the subject of the report which follows.

It will be understood that the inquiry is still in the preliminary stage. For many reasons the differences are not ordered with any regularity, and conclusions based upon the general trend of mean values showing considerable diversity among themselves are liable to modification. There is, however, sufficient evidence to show that the subject deserves further consideration, and it is with the hope of eliciting assistance from those who are practically interested in observations at sea that the paper is placed before the Society.—W. N. Shaw.

A Comparison of Barometric Readings on Land and Sea.

The following is a preliminary investigation into the relation between the barometer readings taken on ships during their passage across a line

between Falmouth and Brest, and the readings deduced for the ships' position from the observations at these places and the trend of the isobars, on the assumption of regular pressure changes. Such an investigation is made desirable in view of the introduction of ships' readings into daily weather charts, as well as from the standpoint of the different land and water effects on the atmosphere. The investigation serves the further purpose of testing the readings taken on board ship on the assumption that the land observations are correct.

The materials for the investigation were taken from meteorological logs at the Meteorological Office. The logs were kept mainly by officers in the merchant service, a few on ships of His Majesty's Navy.

The barometer readings on the ships were taken without exception from Kew pattern mercury barometers reading in general to ·005 in. The barometers have their tubes constricted to prevent pumping, and are all certified at Kew before issue, and are from time to time compared with standards at the Meteorological Office. The index error is never greater than ± ·015 in., and is generally less, at all parts of the scale.

The readings entered in the log are the actual readings taken, with no correction whatever applied; the simultaneous reading of the attached thermometer is in all cases entered alongside the barometer reading. For the purposes of comparison the readings have been reduced to 32° F., and to actual sea-level. The gravity correction has not been applied.

The readings at Falmouth are the hourly readings of the photographic self-recording barograph, corrected by comparison with the eye-readings of a standard instrument. They are published reduced to 32°, and a correction of ·19, ·20, or ·21 in. has been applied to reduce them to mean sea-level. The difference between mean sea-level and actual sea-level does not exceed 10 ft. The readings at Brest are taken three times daily—at 7 a.m., noon, and 8 p.m. They are published reduced to 32°, and a correction of ·24, ·25, or ·26 in. has been applied to reduce them to mean sea-level. The readings for Brest at the time of the ship's observation have been obtained by interpolation when these times differed from those of the Brest observations. The results for 4 a.m. and 4 p.m. have been diminished by ·01 in. to allow for diurnal variation.

The latitude and longitude of the ship have been obtained by dead-reckoning from the nearest noon observation, or from the time when the ship was at some known spot, off Ushant or Eddystone in general. The maximum error of position probably does not exceed 10 miles in any direction. The maximum error therefore in the deduced barometer reading, if the pressure distribution were regular, would not exceed ·02 in., and would generally be much less than this. Falmouth is in lat. 50° 9′ N., long. 5° 4′ W.; and Brest, lat. 48° 24′ N., long. 4° 30′ W.

In the accompanying tables are given the particulars of the observations used. The first five columns give the date, time, position, and ship at which the observation was made. Of the four columns of barometer readings, the 1st gives the reading taken on the ship reduced to 32° and to sea-level. The 2nd and 3rd columns give corresponding results for Falmouth and Brest. The 4th column gives the result deduced from the Falmouth and Brest results for the position of the ship. The remaining columns give the wind observed on the ship, the direction and velocity of the ship, the temperature as given by the dry bulb at the ship

and at Falmouth, and the wind recorded at Falmouth respectively. The velocities are all in miles per hour.

An examination of the tables shows that the pressure, as recorded on the ship, is in nearly all cases considerably less than that deduced from the land observations. The magnitude of the difference varies between wide limits, and at first sight does not appear to follow any law. The results were therefore plotted in various ways, and the diagrams I. and II. obtained.

In Fig. 1 the approximate velocity of the wind relative to the ship

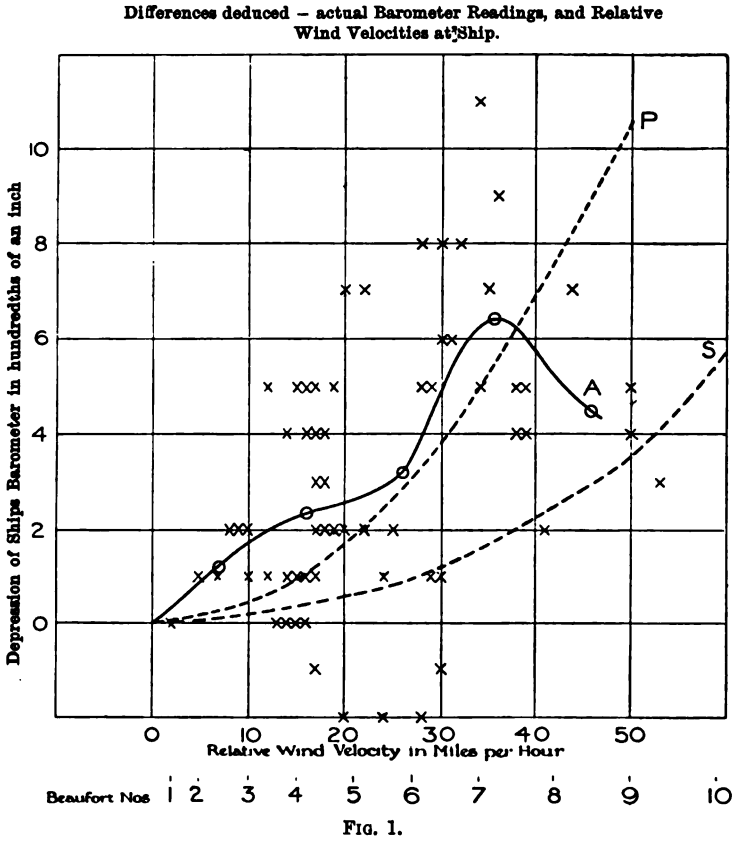

FIG. 1.

is taken as abscissa, and the corresponding depression of the ship's barometer in hundredths of an inch as ordinate. The dotted curve is drawn through the mean points for observations in which the relative wind was between 0 and 10, 10 and 20, etc., miles per hour.

The curve (A) represents the relation between the pressure in hundredths of an inch of mercury and the wind velocity, according to the well-known experimental formula $p = \cdot 003V^2$, or in our units, $p = \cdot 000042V^2$.

Dr. Stanton, Superintendent of the Engineering Department of the National Physical Laboratory, has kindly communicated the result of

experiments on models at the National Physical Laboratory for the depression produced in buildings in which the lee-side doors were open while those on the windward side were closed. The result may be expressed by the formula $p = \cdot 000014V^2$, where p is in inches of mercury and V in miles per hour. The curve S has been drawn to represent this relation.

The barometer on board ship is usually hung in the chart-room, which for purposes of ventilation and convenience generally has the door on the lee-side open, while that on the windward side is closed. In

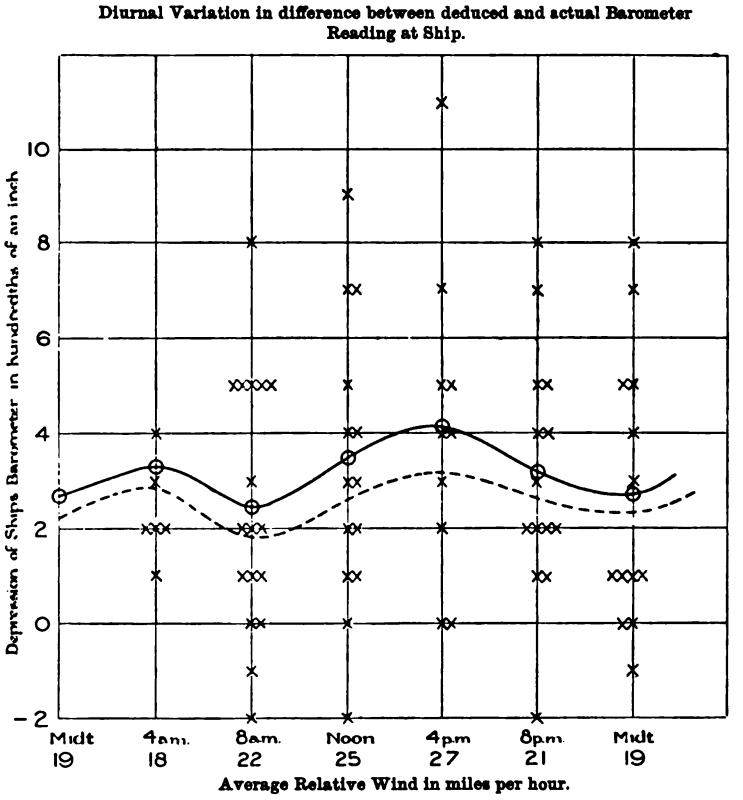

FIG. 2

very high winds both doors may be closed, and any depression caused by the wind can only be due to ventilation. An inspection of Fig. 1 shows that there is on the average a connection between the wind velocity and the barometric depression, but the depression is much larger than would be given by the theoretical curve S. The results roughly correspond to a systematic depression of ·02 in., on which is superposed the depression caused by the relative wind. There are few observations at the higher velocities, but there is a distinct indication of a falling off in the magnitude of the depression corresponding to the closing of the lee-side door.

The results were also plotted according to the time at which the observation was made; Fig. 2 gives the result. There is a small semi-diurnal variation in the mean value of the depression. To eliminate as far as possible the effect on the barometer reading of a diurnal variation in the relative wind velocity, the amount of the depression as given by the curve S for the mean wind velocity at the various hours has been subtracted from the average depression. In this way the dotted curve was obtained, which still shows the double variation.

There is a noticeable grouping of the values of the depression about particular values in the night and early morning observations. In the day-time the results are more evenly distributed. It has been suggested that the large errors are probably due to the observer reading his instrument ·05 in. too low. Such an error is not uncommon even at land stations, and arises through the peculiar method of graduating English barometers in tenths and half-tenths. The observer reads the correct tenth and the correct vernier reading, but omits to add on at times the ·05. If this were the case with the readings under consideration, it would be natural to suppose that a majority of the cases in which the error exceeded ·05 in. would occur when the second figure after the decimal place in the actual reading was less than 5. An inspection of the actual readings proved that there was no such tendency; the number of cases in which this was 1 to 4 was nearly exactly equal to the number in which it was 6 to 9, both for large and for small relative velocities. There is a preponderance of cases in which this figure is 5, 6 out of 31; but this could not materially affect the result, and we are forced to conclude that the depression is not due to any considerable extent to accidental errors of reading.

From the temperatures given for 1903, it appears that in the majority of the observations the temperature at the ship was higher than that at Falmouth. At the same time, the wind velocities over the sea were considerably greater than those recorded at Falmouth. The wind velocities are in miles per hour, those for Falmouth being converted from the Robinson anemograph by using the factor 2·2, while for the ship the table of conversion for single observations, as given in Simpson's report, is used.

There does not appear to be any marked connection between wind direction and the value of the depression, except that for South winds (S.S.E. to S.S.W.) the mean value is about half the average value for other directions.

A comparison of some of the values with the height of the tide did not reveal any connection, but it is possible that the averaged depressions corrected for wind velocity effect would rise and fall with the tide.

There is another effect (on the height of the ship's barometer) which may be of appreciable magnitude, namely, that due to the vertical acceleration as the ship passes over a series of long waves. If the ship is moving across the waves with velocity V relative to them, we may represent the height of the barometer above mean sea-level at any instant by $y = a \sin \frac{2\pi}{\lambda} Vt$, where λ is the wave length.

The vertical acceleration at any instant is therefore

$$\ddot{y} = -a \cdot \left(\frac{2\pi V}{\lambda}\right)^2 \sin \frac{2\pi}{\lambda} Vt.$$

TABLE OF BAROMETRIC READINGS ON SEA AND ON SHORE.

Date.	Time.	Ship.	Lat.	Long.	Barometer reduced to Sea-Level and 32° F.			Barometer at Ship deduced from Falmouth and Brest.	Wind at Ship.	Ship's Velocity.	Temperature.		Wind at Falmouth (2·2 factor).
					Ship.	Falmouth.	Brest.				Ship.	Fal-mouth.	
1901			° ′	° ′	ins.	ins.	ins.	ins.			°	°	
Nov. 5	4 a.m.	Harold	49 10	4 30	*30·29	30·34	30·28	30·31	*ESE 21	S 56 W 9	54	51	E by S 6
5	8 a.m.	Harold	48 54	5 5	*30·33	30·38	30·32	30·34	*E 15	S 56 W 8	52	50	E by N 5
1902													
Mar. 2	12 noon	Montrose	48 38	4 59	*29·93	29·90	29·96	29·95	*W by S 10	S 52 W 13	*53	48	WSW 7
May 10	12 noon	Montrose	48 32	5 8	*30·20	30·21	30·17	30·18	*NE 15?	N 39 E 11	*55	50	SE by S 4
Aug. 8	8 a.m.	Alcinous	49 53	4 30	*29·87	29·87	29·91	29·88	*SW —	...	59	60	Calm
8	Noon	Alcinous	49 49	4 41	*29·93	29·92	29·94	29·93	*Calm	...	64	63	NW 7
8	4 p.m.	Alcinous	49 42	4 50	*30·00	29·98	30·02	30·00	*WNW 15	...	63	61	N by W 11
22	8 p.m.	Arcadia	49 0	5 7	*30·15	30·14	30·21	30·17	*SSE 5	S 49 W 17	*60	60	SSW 7
30	Midnight	Omrah	49 10	4 59	*29·77	29·78	29·89	29·85	*SSW 15	S 27 W 14	61	57	SE by S 9
Sept. 25	,,	East Point	49 45	5 0	*30·45	30·46	30·44	30·45	*NW 2	W 12	*59	54	... 3
28	4 a.m.	Walmer Castle	49 9	4 28	*30·35	30·41	30·38	30·39	*N 2 W 2	S 49 W 19	*59	55	... 3
Oct. 2	Noon	Matatua	48 30	5 11	*29·91	29·84	29·99	29·96	*NE by N 21	S 30 W 9	*67	57	NE by E 10
25	Midnight	Orontes	49 0	5 10	*30·35	30·33	30·39	30·36	*S 1 W 10	S 32 W 15	*54	50	SSW 7
28	8 a.m.	East Point	49 40	5 10	*30·15	30·10	30·18	30·13	*S by E 15	E 11	*56	55	... 2
Nov. 14	8 p.m.	Walmer Castle	49 18	4 10	*30·28	30·31	30·30	30·31	*ENE 5	N 47 E 15	*55	52	SSE 7
14	8 p.m.	Britannia	49 0	4 20	*30·29	30·31	30·30	30·31	*E 7	S 50 W 14	51	52	SSE 7
22	Noon	China	49 39	4 29	*29·98	29·94	30·07	30·00	*S 27	S 48 W 18	*52	53	S by W 11
28	4 p.m.	Arcadia	49 25	4 58	*29·27	29·28	29·36	29·32	*W 15	N 26 E 16	*52	46	SW by S 8
30	8 a.m.	Walmer Castle	48 40	5 5	*29·43	29·49	29·48	29·48	*N 3 W 10	S 30 W 18	*51	44	N 4
Dec. 5	4 a.m.	Omrah	49 5	5 0	*30·37	30·44	30·42	30·43	*E by S 21	N 36 E 15	44	34	NE by N 4
12	8 p.m.	Arcadia	49 0	4 55	*29·97	29·93	30·01	29·98	*S 1 W 15	S 54 W 16	*52	44	SW by W 5
14	8 p.m.	Assaye	49 12	4 45	*30·02	29·85	30·14	30·00	*SSE 35	N 34 E 15	*55	54	S by W 29
20	8 p.m.	Omrah	50 0	4 30	*30·42	30·48	30·52	30·49	*W 10	S 30 W 14	*54	52	NW by N 9
20	Midnight	Omrah	49 0	5 0	*30·48	30·50	30·54	30·52	*NW 10	S 30 W 14	*54	52	NW by N 11
26	Noon	India	49 28	4 17	*30·32	30·38	30·46	30·41	*WNW 27	SW 15	*52	51	WNW 15
26	4 p.m.	India	48 50	5 10	*30·37	30·37	30·44	30·44	*WNW 27	SW 14	*52	50	WNW 15

1903															
Jan. 4	Midnight	Montrose	49	18	4	34	*29·76	29·67	29·88	29·75	*SW by S 27	N 38 E 11	*55	53	SW 28
16	4 p.m.	Walmer Castle	48	50	5	0	*29·79	29·92	29·94	29·90	*SE 35	N 30 E 15	*47	42	SSE 22
29	4 a.m.	China	49	30	4	50	*30·47	30·46	30·53	30·50	*WNW 21	N 23 E 16	*50	44	W 8
30	4 a.m.	Orontes	50	1	4	43	*30·42	30·41	30·49	30·43	*SSW 21	N 40 E 11	*49	45	SW by W 10
31	4 p.m.	Egypt	48	46	5	0	*29·62	29·55	29·71	29·67	*SSW 35	S 42 W 16	*52	46	S 21
31	Noon	Egypt	49	30	4	0	*29·84	29·79	29·92	29·87	*SW by W 35	S 42 W 19	*53	51	S by W 20
Feb. 1	Noon	Walmer Castle	49	0	4	45	*29·50	29·48	29·62	29·57	*WNW 35	S 50 W 13	*42	40	W by S 16
5	8 a.m.	Moravian	48	20	6	5	*30·34	30·37	30·43	30·40	*S by E 15	S 28 W 13	*54	48	SSW 10
14	Midnight	Orontes	49	15	5	10	*30·26	30·24	30·29	30·27	*WNW 5	S 30 W 14	*48	46	NW by N 6
20	8 a.m.	Britannia	48	32	5	38	*30·53	30·44	30·56	30·53	*SW by W 12	N 26 E 15	*55	51	WSW 6
21	4 p.m.	China	49	20	4	54	*30·21	30·14	30·37	30·25	*SW 35	S 49 W 15	*54	54	W by S 24
23	8 a.m.	Sophocles	49	0	5	0	*29·91	29·84	29·99	29·96	*W 27	N 23 E 12	*47	40	W by S 16
Mar. 13	8 p.m.	Britannia	48	50	4	45	*29·90	29·91	29·93	29·92	*N 10	S 50 W 13	48	44	... 1
15	8 p.m.	Orient	49	0	4	50	*29·65	29·62	29·77	29·73	*SSW 21	S 50 W 13	*48	44	SSW 15
20	Noon	Arcadia	49	29	4	49	*30·35	30·29	30·44	30·36	*S by W 15	N 26 E 16	*53	52	SW by W 19
20	4 p.m.	Walmer Castle	49	1	4	12	*30·30	30·29	30·40	30·36	*SSW 10	N 48 E 16	*54	51	SW by S 18
27	4 a.m.	Omrah	49	0	5	0	*29·42	29·44	29·50	29·48	*NW by W 21	N 30 E 16	*49	41	W 8
Apr. 9	8 a.m.	Egypt	49	26	4	50	*30·27	30·28	30·28	30·28	*N 15	N 32 E 16	*50	47	N by E 6
25	8 p.m.	India	49	0	4	58	*29·64	29·64	29·72	29·69	*WSW 15	S 53 W 15	*51	49	S by W 13
25	Midnight	Ormuz	49	7	5	10	*29·57	29·58	29·66	29·62	*SSW 27	S 26 W 13	*50	47	S by W 14
26	Midnight	Orient	49	20	4	40	*29·29	29·26	29·39	29·32	*WNW 10	N 22 E 14	*50	48	WSW 10
May 7	8 p.m.	Britannia	48	51	5	14	*29·67	29·65	29·69	29·68	*SE 10	N 32 E 13	54	51	S by E 9
7	Midnight	Britannia	49	35	4	42	*29·63	29·61	29·65	29·63	*SE 10	N 25 E 13	54	51	SSE 14
15	8 p.m.	Victoria	49	18	4	50	*30·29	30·31	30·36	30·33	*NW 5	N 23 E 15	52	48	WNW 6
22	Noon	Hibernian	48	21	5	12	*30·11	30·08	30·12	30·12	*NW by W 10	N 22 E 12	*54	58	SW by W 15
22	4 p.m.	Hibernian	48	53	4	20	*30·17	30·13	30·18	30·17	*NW by W 10	N 48 E 13	*55	60	SW by W 13
23	4 a.m.	Orontes	49	55	4	35	*30·33	30·35	30·34	30·35	*WNW 15	N 55 E 10	*52	48	NW by N 4
28	8 a.m.	China	49	30	5	8	*29·88	29·92	29·85	29·90	*NE 15	N 28 E 13	*55	58	N by W 7
31	Noon	Moravian	49	22	4	48	*29·80	29·82	29·85	29·84	*NNW 2	N 28 E 13	*57	63	N by W 10
June 6	Midnight	Orontes	49	50	4	30	*30·23	30·30	30·20	30·28	*ESE 15	S 32 W 14	*53	53	E 4
27	Noon	Victoria	49	26	4	21	30·09	30·08	30·09	30·09	Calm	S 42 W 18	65	65	SE 7
July 1	Midnight	Moravian	49	35	5	2	*30·08	30·16	30·12	30·15	*SE 15	S 40 W 13	*58	57	ESE 5
4	8 a.m.	Albertville	48	59	4	44	30·22	30·20	30·26	30·24	W by S 2	S 50 W 13	*61	59	SW by W 4
18	Midnight	Orient	49	5	5	4	*29·84	29·83	29·86	29·85	*SW 5	S 30 W 13	*61	56	... 2
25	4 p.m.	India	48	45	5	1	29·73	29·73	29·85	29·74	S 21	S 53 W 16	61	61	S by W 12
26	8 a.m.	Arcadia	49	17	4	56	*29·86	29·89	29·96	29·91	*WNW 5	N 26 E 16	*61	60	WNW 10

* The Observations marked with an asterisk in the Tables are taken from logs which have been classed by the Meteorological Office as "excellent" or "very good" for these particular observations. The diagrams have been prepared from the rows of observations in which the barometer reading is so classed.

TABLE OF BAROMETRIC READINGS ON SEA AND ON SHORE—(*Continued*).

Date.	Time.	Ship.	Lat.	Long.	Barometer reduced to Sea-Level and 32° F.			Barometer at Ship deduced from Falmouth and Brest.	Wind at Ship.	Ship's Velocity.	Temperature.		Wind at Falmouth (2·2 factor).
					Ship.	Falmouth.	Brest.				Ship.	Fal. mouth.	
1903			° ′	° ′	ins.	ins.	ins.	ins.					
Aug. 1	4 p.m.	Egypt	49 10	4 43	30·13	30·12	30·19	30·16	SW by W 10	S 47° W 15	*61°	64°	NW by W 8
16	4 a.m.	Ormuz	48 20	4 50	29·92	29·86	29·99	29·99	WSW 30	S 47 W 13	57	53	W 10
17	8 a.m.	Ramsay	49 10	4 4	*29·75	29·74	29·91	29·80	*W by S 35	S 56 W 6	*60	58	NW 15
17	Noon	Ramsay	49 0	4 24	*29·88	29·85	29·98	29·92	*W by S 35	S 56 W 5	*61	60	NW by W 15
17	4 p.m.	Ramsay	48 45	4 54	*29·93	29·89	29·99	29·97	*SW by W 15	S 56 W 7	*61	59	W by S 11
21	4 a.m.	Albertville	48 45	4 58	29·57	29·58	29·69	29·66	SW by W 21	N 47 E 13	*60	52	N 8
21	Midnight	Maine	49 5	4 33	29·93	29·90	29·94	29·93	W by N 21	S 55 W 12	*61	60	... 3
Sept. 5	8 a.m.	Albertville	48 57	4 26	29·84	29·80	29·90	29·87	W by S 5	S 50 W 13	*60	58	W by N 13
9	Midnight	Soudan	49 40	5 20	30·18	30·18	30·22	30·19	WNW 21	S 43 W 12	56	52	NW by N 8
11	8 a.m.	Orontes	49 55	4 30	*29·63	29·69	29·79	29·71	*NW 25	N 35 E 16	*55	50	NW 15
19	8 p.m.	Alnwick Castle	49 16	4 22	29·86	29·92	29·82	29·87	E 27	S 52 W 13	*58	56	E by S 11
24	8 a.m.	Egypt	49 10	4 50	30·23	30·25	30·25	30·25	Calm	N 27 E 16	*59	57	... 3
29	4 a.m.	Ramsay	49 0	4 13	*29·69	29·62	29·72	29·71	*S 15	N 54 E 10	*58	57	SSW 5
Oct. 3	Midnight	Victoria	49 35	4 45	29·75	29·72	29·88	29·80	SW 10	N 23 E 15	60	58	SSW 18
4	8 a.m.	Courtfield	49 1	5 3	*29·85	29·77	29·87	29·84	*WSW 21	S 43 W 12	*60	56	W by S 8
25	8 a.m.	Albertville	48 55	4 46	29·28	29·23	29·39	29·34	S 42	N 43 E 13	*57	54	S by W 19
30	8 a.m.	Moravian	49 30	4 45	*29·95	29·93	30·02	29·97	*W 21	N 24 E 13	*56	49	WNW 9
31	8 p.m.	Victoria	48 57	5 29	*29·97	29·93	30·06	30·02	*W 15	SW 16	*57	53	W by N 15
Nov. 7	4 a.m.	Albertville	49 0	4 30	30·34	30·40	30·36	30·38	SE 27	S 51 W 12	51	51	ESE 10
7	8 p.m.	Ophir	49 56	4 27	30·31	30·36	30·33	30·35	E by S 21	S 28 W 11	...	51	E by S 8
10	Midnight	Soudan	50 3	4 30	30·38	30·39	30·44	30·40	WSW 21	ENE 13	52	50	... 4
20	4 a.m.	Ormuz	50 0	4 40	30·28	30·31	30·34	30·31	NW 5	N 40 E 13	49	42	W 6
28	Midnight	India	48 50	5 15	29·23	29·20	29·25	29·24	NW 30	S 57 W 13	50	44	NNW 11
†Dec. 3	Noon	Alnwick Castle	48 47	4 55	†30·20	29·95	30·14	30·07	SE 5	NE 13	*48	45	SSW 23
27	Noon	Albertville	48 40	5 0	29·94	30·05	30·02	30·03	E 21	NE 12	45	40	ENE 8

1906														
Aug. 14	8 a.m.	Loch Torridon	49	45	4	50	*29·61	29·61	29·66	29·63				
14	6 p.m.	Loch Torridon	49	55	5	15	*29·67	29·67	29·75	29·68				
15	8 a.m.	Loch Torridon	49	30	5	30	*29·82	29·79	29·86	29·82				
Dec. 7	8 a.m.	Wakanui	49	10	4	42	*30·32	30·43	30·28	30·35				
20	4 p.m.	Shadwell	48	50	4	45	30·47	30·56	30·48	30·50				
31	8 p.m.	Tongariro	49	25	4	55	*29·69	29·71	29·76	29·73				
1907														
Jan. 12	4 p.m.	Macedonia	49	20	4	20	*30·68	30·69	30·74	30·71				
19	Noon	Wellington	50	54	5	50	*30·43	30·54	30·53	30·50				
26	8 p.m.	Ophir	50	0	4	35	30·62	30·65	30·55	30·64				
Feb. 9	8 p.m.	Omrah	49	53	4	20	29·83	29·86	29·88	29·86				
10	8 p.m.	Athenic	49	40	4	40	29·72	29·70	29·80	29·73				
12	Midnight	Maori	49	20	4	44	29·47	29·50	29·54?	29·52?				
Apr. 15	4 p.m.	Wakanui	48	50	5	0	*29·57	29·60	29·58	29·59				
16	4 p.m.	Shadwell	49	0	4	50	29·61	29·61	29·61	29·61				
25	8 a.m.	Mooltan	49	4	5	0	*30·31	30·35	30·37	30·36				
25	Noon	Mooltan	49	45	4	30	*30·27	30·34	30·32	30·33				
25	Midnight	Tongariro	49	25	5	1	*30·19	30·21	30·19	30·20				
May 3	Noon	Ophir	49	5	4	54	*29·60	29·53	29·71	29·63				
17	4 a.m.	Omrah	49	45	4	30	30·19	30·22	30·18	30·21				
June 5	8 a.m.	Athenic	49	45	4	50	29·72	29·74	29·79	29·75				

* The Observations marked with an asterisk in the Tables are taken from logs which have been classed by the Meteorological Office as "excellent" or "very good" for these particular observations. The diagrams have been prepared from the rows of observations in which the barometer reading is so classed.

† Probably Ship's barometer incorrect. Same reading was entered several times consecutively.

If this condition were permanent the height of the barometer would be $h \cdot \frac{g}{g+\ddot{y}}$, where h is the true height and g the acceleration due to gravity.

If the period be not too small, the motion of the mercury in the constricted tube of the barometer will satisfy an equation

$$\frac{dx}{dt} + q\left(x - \frac{gh}{g+\ddot{y}}\right) = 0,$$

where q is a constant, and x represents the height of the barometer.

In general $\ddot{y}$ will be small compared with g, and we may write this equation

$$\frac{dx}{dt} + q\left(x - h - \frac{ha}{g}\cdot\left(\frac{2\pi V}{\lambda}\right)^2 \sin\frac{2\pi V t}{\lambda}\right) = 0,$$

whence

$$x = h + \beta \sin\left(\frac{2\pi}{\lambda} V t + \epsilon\right)$$

and

$$\beta = q \cdot \frac{ha}{g} \cdot \left(\frac{2\pi V}{\lambda}\right)^2 \times \frac{1}{\sqrt{q^2 + \left(\frac{2\pi V}{\lambda}\right)^2}}$$

The barometric height therefore oscillates, and the amplitude of the oscillation is β.

Taking $q = \frac{1}{240}$ corresponding to a lagging time[1] of four minutes, a to be 10 feet, $\frac{2\pi V}{\lambda} = \frac{1}{30}$, we get

$$\beta = \frac{1}{240} \cdot \frac{1}{30} \cdot \frac{10h}{32} \text{ approximately,}$$

which is only slightly greater than $\frac{1}{1000}$ of an inch.

For waves 100 yards long in deep water, the wave velocity is about 38 feet per second, and the period about $7\frac{1}{2}$ seconds. If a ship steaming 17 knots is meeting such a series of waves we should get $\left(\frac{2\pi V}{\lambda}\right) = 4$ seconds approximately, and the corresponding value of β would be given by

$$\beta = \frac{1}{240} \cdot \frac{1}{4} \cdot \frac{10h}{32} = \cdot 01 \text{ in. approximately.}$$

The height of the barometer would therefore oscillate through a range of ·02 in.; for a greater value of a the range would be proportionally larger.

The effect of the inertia of the mercury has been neglected; its introduction would change t slightly, but would affect the value of β only by changing q in the expression under the square root into $q\left\{1 - \frac{h}{g}\left(\frac{2\pi V}{\lambda}\right)^2\right\}$. This would not materially affect the final value of β, and it can be fairly left out of account.

It may be that in taking the barometer reading at a time when the instrument is "pumping" the observer chooses the instant when the mercury is at its lowest level, and assumes that the correct value is thereby obtained. From the above calculations it would appear that a value so obtained would always be too low, and that a better way would be to observe the highest and lowest readings and to take the mean. It is assumed that the support of the barometer is such as to enable it to

[1] See *Report of the Meteorological Council*, 1880, p. 28.

retain its vertical position, and that its free period of swinging is much smaller than the period of the oscillation of height.

We may investigate the approximate effect of swinging on the barometric height in the following way. The effect produced by swinging is due partly to the upward thrust of the atmospheric pressure when the barometer is inclined, and partly to the outward centrifugal tendency owing to the rotation about the axis.

Let x be the actual length of the mercury column at any instant, let h be the true barometric height for the barometer under consideration, $\frac{1}{q}$ its lagging time, θ its inclination to the vertical, k the distance of the centre of the mercury column below the point of support. Then we may write the equation of motion of the column in the form

$$\frac{q}{g}\ddot{x}\mathrm{A}\int\frac{dh}{a}+\frac{q}{g}\cdot h\cdot k\dot{\theta}^2+\dot{x}+q(x\cos\theta-h)=0,$$

where a is the cross-section at any point and A that at the upper end. For barometer tubes there is generally a constriction in the middle of the tube for a considerable part of the length, and consequently $\mathrm{A}\int\frac{dh}{a}$ is greater than h. Let us call it h'. Further, let us put $\theta = a\sin pt$ where a is small. The equation of motion may then be written

$$\frac{qh'}{g}\ddot{x}+\dot{x}+q\Big\{x-h-\frac{xa^2}{4}+\frac{kh}{2g}\cdot a^2p^2+\frac{xa^2}{4}\cos 2pt+\frac{kh}{2g}a^2p^2\cos 2pt\Big\}=0.$$

The solution of this equation is

$$x=h\Big(1+\frac{a^2}{4}-\frac{ka^2p^2}{2g}\Big)+\beta\sin(2pt+\psi),$$

where

$$\beta=\frac{q\frac{ha^2}{4}\Big(1+2\frac{kp^2}{g}\Big)}{\sqrt{4p^2+q^2\Big(1-4\frac{p^2h'}{g}\Big)^1}}.$$

Putting $q=\frac{1}{240}$, $h=2{\cdot}5$ ft., $h'=2h=5$, $\frac{2\pi}{p}=1$, $g=32$, $k=4$ ins. $=\frac{1}{3}$ ft., $a=0{\cdot}1$, in this expression we find $\beta={\cdot}00005$ in. nearly.

In this case, therefore, the oscillation is negligible. The mean value of x is, however, given by

$$x=h\Big\{1+\frac{a^2}{4}-\frac{ka^2p^2}{2g}\Big\}$$
$$=h\{1+{\cdot}0025-{\cdot}0021\}=h\{1+{\cdot}0004\},$$

and the barometric height would consequently be about ·012 in. too high.

The actual value of p for a station barometer here[1] is given by $\frac{2\pi}{p}=1{\cdot}5$. The corresponding value for x with a and k as before would be

$$x=h(1+{\cdot}0025-{\cdot}0009)=h(1+{\cdot}0016),$$

and the mean reading would be about ·05 in. too high.

It is not easy to test this for a station barometer because the mercury falls too rapidly if the barometer is brought to rest, but for a marine barometer the test ought not to be difficult. It is to be noted that the range of oscillation alone depends on the value of q and, therefore, on the constriction: the mean value of x is independent of q. From a rough

[1] At Cambridge, Barometer M.O. 963.

trial the barometer here, M.O. 963, appears to read nearly ·045 in. too high for a swing through an angle corresponding to $a = 0{\cdot}1$ and ·20 for $a = 0{\cdot}2$ in good agreement with the theoretical amounts. Both for swinging and for the rise and fall of the ship some time must elapse before the steady oscillatory state is reached.

Taking into account, therefore, the various causes which can appreciably influence the height of the barometer on board ship, we are compelled to say that until the two chief ones at any rate, the wind and the vertical acceleration effects, are eliminated, it will be impossible to draw any satisfactory conclusions regarding the relative values of atmospheric pressure over sea and land. One can say in general that there appears to be a tendency for the barometric pressure to be lower between Falmouth and Brest than would be expected from the land observations.

DISCUSSION.

Capt. M. W. C. Hepworth said he had listened with a great deal of pleasure to Mr. Gold. He understood that the inquiry was still in a preliminary stage, and hoped Mr. Gold would follow up the investigation which promised to have important results. In carrying on the work he thought Mr. Gold might be able to obtain the assistance of a number of marine observers who would be interested in it and take specially careful observations. He would suggest that the barometric observations should be recorded to three places of decimals; that the position of the ship should be accurately noted—it would not be sufficient accuracy to give the position to within ten miles as stated: captains who were contented to navigate their ships to within a handful of miles in the Channel came to grief. Other details should also be given, such as the direction and force of the wind on the water, as estimated by the observer, and also as he felt it on the ship; the speed of the ship; its motion, and the rise and fall of the vessel with the scud of the sea. Mr. Gold would then have a number of reliable observations to work on. The difficulty of obtaining sufficient observations for the present inquiry arose in consequence of the fact that observers were so busy in the Channel with other duties, that they were not, as a rule, able to commence observations until past Ushant. Mr. Gold considers that this investigation serves the further purpose of testing the readings taken on board ship, on the assumption that the land observations were correct; but he, Captain Hepworth, felt inclined to suggest that the process be reversed! For some twenty years or more he had been in a position to judge of the general accuracy of barometric observation taken by sailors on board ship, and during the last eight years he had had the opportunity of testing the capabilities of land observers in that respect, and he had come to the conclusion that seamen were as good observers as landsmen. With regard to the pumping of the barometer in a seaway, he thought the observations should be taken—that is to say, the vernier set—when the mercury had touched its lowest level, instead of observing the highest and lowest, and taking the mean. With large ships, such as the *India*, referred to by Mr. Gold, there was in the Channel, as a rule, very little pitching and rolling, rise and fall, as they are borne on three waves; so there should be only small errors from these causes. In comparing barometric observations taken at sea with those deduced from land observations taken at some distance off, there was room for a considerable amount of error, but he would let that pass. After all the sources of error which Mr. Gold had told them of had been eliminated, he would still expect to find a difference between

the sea observations and those deduced from the land observations. If they looked at any of the wind charts of the great oceans, and examined the wind arrows round the coast, they would see that the wind had a tendency to cling to the land. This is shown to some extent on the Daily Weather Charts of the Meteorological Office. Probably Mr. Brodie and his assistants in the Forecasting Branch of the Office, took this into account when watching for the backing wind on the coast of Ireland. Whether the land was high or low there was a tendency for the wind to follow the coast-line in all parts of the world. He thought that, superposed on the general pressure distribution, there existed a gradient between land and sea, and accounted for it in that way. Twenty-five years ago he had first mentioned this fact in a paper he had contributed to the Society.

Dr. W. N. SHAW wished to point out that the question raised in the paper was one of practical scientific importance. As regards the observations, it might be assumed that the observers on land and sea were equally accurate; it was not the competence of the observers that was in question, but the readings which an instrument would give under different conditions, as represented by exposure in an observatory on land and on a ship at sea. The question of barometer readings was not a new one. The Observatory at Ben Nevis had been greatly hampered by the fact that barometer readings had to be rejected —not corrected—when the wind exceeded force 3 on the Ben Nevis scale, because they were too much affected by the wind in those circumstances. That great enterprise was continued for 20 years, and if they considered that meteorology only began to be interesting when the wind got beyond force 3 they would understand the gravity of the question under discussion. In another part of the world a proposal to incorporate land and sea observations, for daily charts, was in danger of being given up because the apparent probable error of an observation at sea was of the order 0·04 in. This state of things ought not to be accepted after fifty years of meteorological study. They were grateful to Mr. Gold for bringing the matter into the light of facts, and enabling them to get some criteria as to the extent of the difference to be expected in different circumstances.

Until the facts of the present inquiry were set out he had supposed that the difficulties of barometric readings at sea or in winds were expressed by what is known as "pumping," but presumably there was a definite pressure difference as well. If he recollected rightly, Professor Cleveland Abbe had described a contrivance for obviating the effect of pumping, by having the barometer in a closed case which communicated with the free air by means of a pipe terminating in a double flange. In view of the information now before us, it would be interesting to consider what the possible effect of wind could be upon a barometer if the position were chosen to exhibit that effect to the greatest extent.

With a barometer in a closed room communicating with the outside by a tube bent to face the wind, the pressure recorded in inches of mercury would be greater than the true pressure in the flowing air by a quantity equal to $\cdot 000042V^2$, as shown by Mr. Gold. This was the maximum interference which could be got with the barometer in consequence of wind blowing directly on the mouth of the communication between the outside air and the room containing the barometer. On the other hand, if they placed a barometer in a closed room, and took up a pipe arranged so that the wind blew across the opening, the effect upon the readings would be of about the same magnitude; but in the opposite direction, the recorded pressure would be less than the true pressure by $\cdot 000042V^2$. These variations amount to about ·05 in. for wind of 35 miles per hour, just reaching gale force. Thus if two barometers were compared, and one were subject to the effect of direct impact of the wind and

the other to the effect of suction due to cross blowing, they might show a difference of 0·1 inch in a 35-mile wind. This is the greatest amount of difference attributable to such causes even in extreme conditions for a wind of that velocity. If, however, there were two openings, one directly exposed to the wind, and the other having the wind blowing across it, the two acting together therefore, if properly adjusted, would counteract each other and produce no change of pressure at all. The first conclusion from the paper was that they seldom found a barometer exposed under those conditions.

The conditions of actual exposure of two barometers might be anything between the extremes on either side, and thus a comparison of the two for a 35-mile wind might show anything between +0·1 and −0·1 according to circumstances.

The next conclusion to be drawn was, that the exposure on board ship as a rule is such, that the barometer readings show the effects of "suction" as compared with the barometer at Falmouth Observatory.

The inquiry is still in a preliminary stage because the number of observations is small. A sufficient number of observations would enable them to tell how to expose a barometer in order to know what the amount of error would be, and therefore what correction would be required.

As regards the last part of the paper, he must thank Mr. Gold for including the solution of the problems of the effect of the rise and fall of the ship in a train of waves, and the effect of a pendular oscillation. It was very convenient to have the magnitude of the errors due to those causes ascertained.

Mr. H. HARRIES said that Mr. Gold was to be congratulated on the success which had attended his very interesting investigation of a problem, the importance of which had probably not hitherto occurred to meteorologists. Practical experience, however, shows that at many land stations the pressure observations are as unreliable as those taken at sea, similar causes producing similar results. Last Friday evening (February 14) there was a very rapid decrease and increase of pressure on our north-western coasts, accompanied by high winds. At one station, where the barometer is in a hut on a very exposed headland, and with an over-abundance of roof ventilation, the barogram is formed of a series of violent oscillations, producing a curve which at times has a breadth of 0·1 in. or more. At a neighbouring station, where the barometer is suspended in the observer's private house, and properly protected against varying air currents, the barogram is a beautifully smooth and regular curve, absolutely free from any irregular fluctuations. Investigation will probably result in proving that all barometers fixed in tall, chimney-like structures, such as lighthouse towers, read too low in consequence of an up-draught, which in lighthouses would be greatly strengthened by the heat from the illuminating machinery on the upper floors, reducing the barometric pressure by as much as 0·05 in. These may be described as artificial conditions of exposure, but in Southern Europe we are provided with an illustration of the same thing on a vast natural scale. The Alpine range, rising to between 10,000 and 16,000 feet, towers above the plains of North Italy. When the general atmospheric conditions favour strong Westerly winds and gales above this high wall, so great is the suction of the air from the plains on the lee side that the barometer readings at Turin, Milan, Cremona, Verona, and other observatories, are not only hundredths, but actually tenths of an inch lower than if the Alpine barrier did not exist. On the other hand, when the conditions produce a steady flow of easterly wind, such an excess of air becomes imprisoned within the basin that the barometer rises very much higher at these stations than at neighbouring ones on the French side of the Alps.

Mr. R. INWARDS remarked that it did not seem to him impossible to get more extended experiments by means of Marconigrams, or other signals—say on

a voyage along the coast of Portugal so as to take land and sea observations at the same time. They would then get some really sound facts, and thus prepare the way for calculations and deductions.

Capt. R. C. WARDEN remarked that he had been very interested in the point regarding the fluctuations of a ship's barometer. He had had two barometers on board ship, one hanging in the entrance to the staircase, and the other in a cupboard in the chart room. In the China seas, where the barometer was watched with the greatest care during the passage of two typhoons, the observations from the two barometers differed greatly, though in ordinary weather their readings agreed. The barometer on the staircase became quite demoralised for no apparent reason, and the readings were most unreliable. The other barometer gave most accurate results. He was greatly indebted to Mr. Gold for supplying a possible explanation for this fact, as hitherto he had failed to understand why the barometer on the staircase should have become useless; and on behalf of seafaring men he thanked Mr. Gold for his investigations.

Meteorological Work at the Royal Observatory, Greenwich, 1907.

The Meteorological observations by eye and by self-recording instruments have been maintained as usual, and the special observations of clouds on selected days in each month have been continued at the request of the International Balloon Committee, a Fineman nephoscope having been used for this purpose.

Daily reports have been issued as in previous years; weekly meteorological returns furnished to the Registrar-General; monthly returns of temperature, rainfall, and sunshine to the Royal Meteorological Society; and monthly reports (instead of quarterly as in recent years) to the Meteorological Office.

The temperature of the air ranged between 82°·7 on September 25, and 22°·4 on January 24. 1907 was thus the third year having its highest temperature in September, a feature unknown in the first fifty-four years of the Greenwich records; and this highest temperature occurred later than in any other year of the series, that in 1895 being on September 24. The only other daily maximum reaching 80° during the year was 81°·5 on May 12. Instances of readings of 80° and upwards in May only have occurred before, in 1841 and 1862; but 1907 is unique in showing such readings before and after, but not during, what are regarded as the three summer months. The daily maximum reached 80° twice only in 1841 and 1853, once only in 1862 and 1879, and not at all in 1860, when the highest reading, 76°·5, was in May.

Notwithstanding the absence of high temperature readings in the summer the mean temperature for the year was 49°·4, or only 0°·2 below the average for the 65 years 1841-1905, the outstanding months being July 4°·0 below, June 2°·9 below, and March 2°·4 above the corresponding average values.

The duration of sunshine recorded in the year was 1417 hours, the sun having been above the horizon for 4459 hours, so that the total fell short of the average for 1897-1906 by 85 hours. March, however, was the sunniest on record at Greenwich with 170 hours of bright sunshine. The greatest actual duration on a single day was 13·5 hours on June 16, but the greatest percentage was 88·4 per cent on August 28, so that the intensity as well as the duration appears to show a decided falling off in comparison with the exceptional conditions of the preceding year. There were, during 1907, 71 days on which no register of sunshine was obtained, one of these days occurring in each of the months June, July, August, and September.

The highest reading of the solar radiation thermometer with blackened bulb *in vacuo* was 142°·3 on June 9 (again a distinct falling off in comparison

with 1906), and the lowest reading on the grass was 8°·8 on January 25. The difference between the "highest in the sun's rays" and the "lowest on the grass" exceeded 100° on only 5 days (as against 32 in 1906), the maximum difference, 107°·8, being one of the features of the phenomenally fine Easter Day, March 31.

The number of days when air temperatures of 32° or less were recorded was 45, of which the first three months were responsible for 37, and the cold night of April 18-19 for two more, leaving only six for the end of the year. December with one night-frost (December 15-16), accounting for two of these, was thus on a level with April.

On the ground, the number of days similarly counted with readings of 32° and under was 133. Using the Meteorological Office limit of 30° and under the number of days was 103, which is further reduced to 86 by considering the night as the unit instead of the day.

Rain fell on 163 days in the year to the total amount of 22·250 ins., being 1·872 in. less than the average for the 65 years 1841-1905. The driest month was September with 0·623 in.; the actually wettest was October with 3·252 ins., but the relatively wettest was April with 3·139 ins. The greatest fall in one day was 1·026 in. on June 29, the exact anniversary of the wettest day in 1906. Falls of more than half an inch occurred also on April 26, June 1, November 18, 26, and 27, December 12 and 13. An exceptionally long period without rain was one of nineteen days from September 7 to September 25 inclusive.

The greatest recorded pressure of the wind was 23·0 lbs. to the square foot on March 19. On five other days pressures exceeding 20 lbs. to the square foot were recorded. The greatest daily velocity was 936 miles on February 20, and the least 22 miles on September 12. The greatest hourly velocity was 50 miles for the hour ending at noon on February 20. The total movement for the year was 103,281 miles, the greatest monthly movement being 11,450 miles in December, and the least 5157 miles in September. The summer was exceptionally windy; a comparative lull in July, however, enabled 1882 to retain its "record" for the three months total, though June 1907 with 10,606 miles was easily the windiest June in the Greenwich records, beating 1882 by 867 miles. The mileage for the three summer months was 27,025, as against 28,117 in 1882.

A discussion of 40 years' homogeneous records of the Robinson anemometer is in progress, but changes in the staff have greatly hindered it, the only portion actually adopted for use being the daily average, for which, from January 1, 1907, a table constructed similarly to that in use for daily temperature has been employed.—WALTER W. BRYANT, for the Astronomer Royal, March 17, 1908.

REPORT OF THE COUNCIL

FOR THE YEAR 1907.

[Submitted to the Annual General Meeting, January 15, 1908.]

IN presenting their Report, the Council observe with pleasure the marked and increasing interest which is being taken in the science of Meteorology throughout the country. The Lectures and Exhibitions inaugurated by the Society are bearing fruit; and that the efforts of the Society are appreciated, is shown by the large increase in the roll of the Fellows, who now exceed 700, a number which has never before been reached.

Amongst the losses by death the Council have to record the names of six Fellows who have done good service to Meteorology in various ways. Dr. Robert Barnes and Admiral John Pearse Maclear were for some time members of their body; Dr. Alexander Buchan was the first recipient of the Symons Memorial Medal; Mr. Henry Chamberlaine Russell was the Government Astronomer for New South Wales; Dr. Wilhelm von Bezold of Berlin, an Honorary Member, was the head of the Prussian Meteorological Institute; and Dr. Maurits Snellen, also an Honorary Member, was formerly the head of the Meteorological Institute of the Netherlands.

Committees.—The Council have been materially assisted during the year by the following Committees:—

EDITING COMMITTEE.—The President, Messrs. Bayard, Bentley, Inwards, and Scott.

GENERAL PURPOSES COMMITTEE.—The President, Secretaries, Treasurer, Messrs. Bentley, Inwards, Latham, and Shaw.

KITE COMMITTEE (to co-operate with other bodies for the promotion of the study of the Upper Atmosphere).—The President, Secretaries, Col. Capper, Messrs. Cave, Curtis, and Capt. Hepworth.

LOCAL SCIENTIFIC SOCIETIES COMMITTEE.—The President, Secretaries, Treasurer, Messrs. Bentley, Clark, and Druce.

Co-operation with the Meteorological Office.—The Council regret that, as concurrence on the part of all the meteorological authorities interested has not yet been secured, the Meteorological Office has not been able to carry out the scheme for a joint publication of Monthly Summaries of Observations for the British Isles. The matter is being kept in mind, and the Council trust that before long the desired end will be attained. The arrangements under which certain meteorological data are supplied by the Society to the Meteorological Office have been revised at the request of the Director.

Symons Memorial Medal.—The Council have awarded the Symons Gold Medal for 1908 to Monsieur Léon Teisserenc de Bort, in consideration of the distinguished work which he has done in connection with meteorological science, especially the study of the upper air.

Howard Medal.—The Howard Medal, which is competed for annually by the Cadets of the Nautical Training College, H.M.S. *Worcester*, was won by Cadet Dennis Duncan Philby, for an essay on "The Meteorology of the Atlantic."

Lecture.—Major B. F. S. Baden-Powell delivered a Lecture before the Society on March 20, on "The Exploration of the Air," which was illustrated by models and lantern slides.

Kite Committee.—This Committee co-operates with a Committee of the British Association and with the Meteorological Office. The Kite work at Glossop Moor, Derbyshire, has been continued under the direction of Mr. J. E. Petavel, F.R.S., and ascents have been made when circumstances permitted. A paper embodying a discussion of the Kite observations made at the four stations in England during 1906-7 was read at the November meeting of the Society.

The Committee have learned with much pleasure that mainly through the liberality of Dr. Arthur Schuster, a Fellow of the Society, the University of Manchester has been enabled to place the station at Glossop Moor upon a satisfactory footing for two years from January 1, 1908, at an estimated cost of about £1000. The station is to be known as the Howard Estate Meteorological Station of the University of Manchester, and systematic observations of the upper air will be carried on there for the period named. The Committee have been asked and have agreed to provide a captive balloon for the Howard Estate Station, which is intended for use in calm weather. This will furnish observations of the upper air under quiet conditions, which hitherto have not been possible.

Systematic observations are also carried out by Mr. Dines, for the Meteorological Office at Pyrton Hill, Oxfordshire, by Mr. Cave at Ditcham Park, Petersfield, and by Mr. S. H. K. Salmon at Brighton. On the invitation of the International Commission of Scientific Aeronautics the Committee resolved to take part during the years 1907 and 1908 in an international scheme for the investigation of the Upper Atmosphere, by means of *ballons-sondes* carrying self-recording instruments, and of smaller balloons, the height and drift of which would be determined by angular measurements. For this purpose, in the past year the Joint-Committee, besides assisting in the maintenance of the Glossop Moor Station, arranged for special stations at Sellack, near Ross, Herefordshire, and at Dublin, with the co-operation of Captain Ley and of Professor Thrift respectively, and the Meteorological Office made provision for a series of ascents at Crinan, Argyleshire. Ascents were made on July 22 to 27, September 4, 5, and 6, and November 6, 7, and 8. The ascents have been successful, and reports summarising the results have been laid before the Society. A supply of pilot balloons, and also a cylinder of hydrogen gas, were sent out to Professor D'Albuquerque at Barbados, who made theodolite observations on the height and drift of balloons on November 6 to 8. Towards the expenses of the Committee's share of this investigation the Government Grant Committee of the Royal Society made a grant of £100, and in response to a letter to the Fellows of our Society issued by the Council, additional subscriptions of £40 : 16 : 6 have been received. The arrangements for 1908 are not yet completed, but the British Association has reappointed its Committee to co-operate with the Kite Committee, with a grant of £25. The Council gratefully acknowledge the services of the observers mentioned.

Local Scientific Societies' Committee.—In connection with the Society's scheme for diffusing a knowledge of Meteorology, Mr. Marriott has during

the past year delivered lectures at nine centres in various parts of the country. At the Lincoln Show of the Royal Agricultural Society on June 25 to 29, a Meteorological Exhibit, including a typical Climatological Station, was arranged, and addresses were given by Mr. Marriott. In connection with this Show a well-attended Conference was held on the question of Nature Study in Schools, in which one of the subjects discussed was "that Elementary Meteorology is a desirable subject for rural education."

With reference to the Elementary Schools, the Committee have offered for competition by Elementary Teachers and others, three prizes of £5, £3, and £2, for the three best papers embodying a Nature Study Lesson on Weather and Climate, together with a synopsis of five other lessons suitable for children.

The Committee sent letters to the Board of Agriculture and Fisheries, the Royal Agricultural Society, the Highland and Agricultural Society, and a number of the Agricultural Colleges, calling attention to the bearing of Meteorology on Agriculture and Horticulture.

The President, on behalf of the Society, gave evidence before the Departmental Committee on Agricultural Education on the subject of Meteorology and Agriculture. Replies to these letters have been received and are now being considered.

The Geological Society's Centenary.—The Geological Society invited this Society to send a delegate to its Centenary Celebration on September 26 to 28, and at the request of the Council the President represented the Society on the occasion.

Franco-British Exhibition.—The Council having received an invitation to send a representative to serve on the Science Committee, nominated the President. Several Fellows of the Society are members of the sub-committee which has been appointed to arrange a Meteorological Exhibit.

Research Fund.—This fund is represented by £72 : 11 : 5 Consols. No grants have been made from it during the year, nor has it been increased by new donations.

Meetings.—With the exception of those in May and June, which were held in the Society's rooms, the Meetings took place as in former years, by the courtesy of the President and Council of the Institution of Civil Engineers, at their house in Great George Street, Westminster.

Dinner.—A successful Dinner of the Society was held at the Trocadero Restaurant, on Tuesday, June 18, at which seventy-five gentlemen, including a number of distinguished guests, were present. The Council hope that it will become an annual function, and be attended by the Fellows in increasing numbers.

Publications.—The volume of the *Quarterly Journal* for 1907 consists of 320 pages, and contains the papers read at the Meetings of the Society, with an abstract of the discussions that followed, correspondence, and numerous notices of meteorological interest. The section of "Meteorological Literature" has been continued as a special feature.

Four parts of the *Meteorological Record* have been issued during the year, bringing this publication up to December 1906.

For Continuation of Report of the Council, see page 122.

APPENDIX

STATEMENT OF RECEIPTS AND EXPENDITURE

RECEIPTS.

Balance from 1906			£321 3 1
Subscriptions for 1907	£865 0 0		
Do. for former years	43 0 0		
Do. paid in advance	92 0 0		
Life Compositions	308 0 0		
Entrance Fees	106 0 0		
		1414	0 0
Meteorological Office—Copies of Returns	£98 15 3		
Do. Grant towards Inspection Expenses	25 0 0		
		123	15 3
Dividends on Stock (including £47 : 19 : 10 from the New Premises Fund)		147	4 6
Sale of Publications, &c.		31	3 7
Advertisements		24	5 6
		£2061	11 11

I.

FOR THE YEAR ENDING DECEMBER 31, 1907.

EXPENDITURE.

Journal, &c.—			
Quarterly Journal, Nos. 141 to 144	£162 0 6		
Illustrations	30 2 6		
Authors' Copies	15 14 6		
Meteorological Record, Nos. 101 to 104	86 6 6		
		£294	4 0
Printing, &c.—			
General Printing	£20 16 0		
Stationery	16 19 7		
Books and Bookbinding	20 8 11		
		58	4 6
Office Expenses—			
Salaries	£607 16 9		
Rent	212 0 0		
Coals, Lighting, and Insurance	15 5 6		
Casements, Furniture, and Repairs	25 19 0		
Postage	73 3 3		
Petty Expenses	9 4 5		
Refreshments at Meetings	14 5 7		
Telephone	6 10 0		
Lecture	10 10 0		
Two Howard Medals	2 8 6		
		977	3 0
Observations—			
Inspection of Stations	£60 5 0		
Observers	11 4 0		
Instruments	4 3 0		
		75	12 0
Stock—			
Purchase of £145 : 2 : 0 New South Wales 4 per cent Inscribed Stock at 108		156	15 2
		£1561	18 8
Balance—			
At Bank of England	£187 4 9		
At London and Westminster Bank—Deposit	300 0 0		
In hands of the Assistant-Secretary	12 8 6		
		499	13 3
		£2061	11 11

Examined, compared with the vouchers, and found correct,

January 8, 1908.

T. P. NEWMAN,
J. W. FORRESTER, } *Auditors.*

APPENDIX

ASSETS AND LIABILITIES

LIABILITIES.			
Subscriptions paid in advance	£92 0 0		
Rent for quarter ending December 25, 1907	53 0 0		
		£145 0 0	
Excess of Assets over Liabilities		3730 19 6	
		£3875 19 6	

WM. MARRIOTT, *Assistant-Secretary.*

NEW PREMISES FUND,

Interest received on Investment	£47 19 10

RESEARCH FUND,

Interest received on Investment	£1 15 6

I.—continued.

ON DECEMBER 31, 1907.

ASSETS.

Great Central Railway 4½ per cent Debenture Stock, £800 at 120	£960	0	0			
New South Wales 4 per cent Inscribed Stock, £800 at 105	840	0	0			
London & North-Western Railway Consolidated Stock, £400 at 149½	598	0	0			
London & North-Western Railway 4 per cent Preference Stock, £12 at 114	13	13	7			
Annuities, 2½ per cent, £231 : 11 : 9 at 82¼	190	9	7			
				£2602	3	2
Subscriptions unpaid, estimated at	£42	0	0			
Entrance Fees unpaid	23	0	0			
Interest due on Stock	57	13	5			
Interest on Deposit at London and Westminster Bank	8	13	0			
Meteorological Office—Weekly Returns, 1907	28	10	11			
Sale of Publications by E. Stanford, 1907	31	6	9			
				191	4	1
Furniture, Fittings, &c.	£465	16	3			
Instruments	117	2	9			
				582	19	0
Cash at Bank of England	£187	4	9			
Cash in hands of the Assistant-Secretary	12	8	6			
Deposit at London and Westminster Bank	300	0	0			
				499	13	3
				£3875	19	6

Examined, and Securities seen at the Bank of England,

January 8, 1908.

T. P. NEWMAN,
J. W. FORRESTER, } *Auditors.*

DECEMBER 31, 1907.

Amount paid to the Society's Fund towards the rent of offices at 70 Victoria Street £47 19 10

Note.—The Society holds on account of this Fund £1443 : 7 : 9 South Australian 3½ per cent Inscribed Stock.

Examined and found correct,

January 8, 1908.

T. P. NEWMAN,
J. W. FORRESTER, } *Auditors.*

DECEMBER 31, 1907.

Cash at Bank of England £1 15 6

Note.—The Society holds on account of this Fund £72 : 11 : 5 Consols.

Examined and found correct,

January 8, 1908.

T. P. NEWMAN,
J. W. FORRESTER, } *Auditors.*

APPENDIX

SYMONS MEMORIAL MEDAL

Balance in hand from 1906	£31 4 11
Interest received on Investment	18 18 0
	£50 2 11

LOCAL SCIENTIFIC SOCIETIES'

Balance from 1906—		
Deposit at London and Westminster Bank	£100 0 0	
Interest on ditto	3 11 11	
Cash at Bank of England	28 16 10	
Ditto in hands of Assistant-Secretary	7 7 9	
		£139 16 6
Contributions—Capt. Hepworth		1 1 0
,, Mr. Mellish		5 0 0
Lectures—Fees and Expenses		45 17 6
		£191 15 0

KITE OBSERVATION

Balance in hand from 1906	£74 8 1
Grant from the Royal Society Government Grant Fund	100 0 0
Contribution—Anonymous Donor	25 0 0
Do. Mr. D. Buckney	1 1 0
Do. Capt. M. H. Clarke	0 10 6
Do. Mr. F. Druce	2 2 0
Do. Mrs. Lyndon	1 1 0
Do. Mr. H. Mellish	2 0 0
Do. Mr. R. W. Munro	2 2 0
Do. Mr. C. M. Powell	5 0 0
Do. Mr. J. T. Southall	2 0 0
	£215 4 7

I.—continued.

FUND, DECEMBER 31, 1907.

Cash at Bank of England, December 31, 1907	50 2 11
	£50 2 11

Note.—The Society holds on account of this Fund £630 Cardiff Corporation Redeemable Stock, 3 per cent.

Examined and found correct,

January 8, 1908. T. P. NEWMAN, J. W. FORRESTER, } *Auditors.*

FUND, DECEMBER 31, 1907.

Lecturer's Fees and Expenses		£35 2 4
Exhibit at Royal Agricultural Society's Show		33 8 8
Lantern Slides and Diagrams		2 13 0
Instruments		0 18 11
Fillets for Frames		1 10 0
Printing, Postage, etc.		7 15 2
Advertisements *re* Prize Competition		1 11 6
		£82 19 7
Balance—		
Cash at Bank of England	£7 7 9	
Do. in hands of the Assistant-Secretary	1 7 8	
Deposit at London and Westminster Bank	100 0 0	
	108 15 5	
		£191 15 0

Examined and found correct,

January 8, 1908. T. P. NEWMAN, J. W. FORRESTER, } *Auditors.*

FUND, DECEMBER 31, 1907.

Balloon Observations at Manchester	£34 4 1
Do. do. at Sellack	31 19 4
Meteorographs	6 0 0
Rewards	1 0 0
Hydrogen for Barbados Observations	5 18 4
Indiarubber Balloons	0 18 0
	£79 19 9
Cash at Bank of England, December 31, 1907	135 4 10
	£215 4 7

Examined and found correct,

January 8, 1908. T. P. NEWMAN, J. W. FORRESTER, } *Auditors.*

Stations.—In consequence of the removal of the observers, observations have been discontinued at Market Drayton, Shropshire; Pirbright, Surrey; and Southwold, Suffolk. The Council have accepted observations from the following new Climatological stations:—Bournemouth, Hants; Brookwood and Burgh Heath, Surrey; Killerton, Devon; Midhurst, Sussex; Sandwich, Kent; and Ware, Herts.

Inspection of Stations.—Forty-six stations, chiefly in the west and south-west districts, were inspected by Mr. Marriott, and found to be on the whole in a satisfactory condition. Mr. Marriott's report will be found in Appendix II., p. 123.

Phenological Report.—This report was prepared as usual by Mr. E. Mawley, and read at the February meeting. The Society owes its best thanks to Mr. Mawley for his labours in collecting and discussing the returns from 108 stations, and for keeping in communication with so large a body of special observers during so many years.

Library and Bibliography.—As the serial publications have increased beyond the space provided for them, those books which do not bear upon meteorology have been eliminated, and the remaining serials have been rearranged on the shelves. This rearrangement necessitated the alteration of the shelf numbers on the catalogue slips, and the revision of the slip catalogue has been taken in hand. The Subject Classification adopted in 1901 having proved insufficient, the revised Subject Classification of the *International Catalogue of Scientific Literature* has been adopted with certain modifications and additions. The Catalogue is being prepared in two parts:—(1) List of titles in alphabetical order of authors and institutions, each slip bearing the subject registration number in the top right-hand corner; and (2) a subject catalogue, each sub-section containing the titles of all works relating to that registration number in the subject catalogue. Up to the end of the year 5461 authors' slips and 6299 subject slips have been dealt with. The additions to the Library will be found in Appendix V., p. 139. During the year 4649 cards have been prepared for the Society's Bibliography; and 256 authors' slips and 411 subject slips of titles of works bearing on Meteorology, published in the British Isles, have been made for the *International Catalogue of Scientific Literature.* The Council have to express their recognition of the courtesy of the Editor of the *Geographical Journal* for supplying advance proofs of the monthly Bibliography prepared for that publication.

Office Staff.—The Council have found it necessary to engage an additional junior assistant, and they trust that with this help the staff can carry on the work of the office with its wonted efficiency. The work and usefulness of the Society have during recent years increased in many directions, and the Council recognise the efforts made on the part of the staff to cope with it.

Offices.—As the noise of motor and other traffic in Victoria Street has increased to such an extent as to interfere with work, the Council have directed that double windows be fitted in the rooms facing the street.

Fellows.—The changes in the number of Fellows are given in the following table:—

Fellows.	Annual.	Life.	Honorary.	Total.
1906, December 31	500	149	20	669
Since elected . . .	+ 120	+ 9	...	+ 129
Since compounded .	− 5	+ 5	...	0
Reinstated	+ 1	...	...	+ 1
Deceased	− 13	− 4	− 2	− 19
Retired	− 23	...	...	− 23
Removed from List .	− 16	...	...	− 16
Lapsed	− 9	...	...	− 9
1907, December 31	555	159	18	732

Deaths.—The Council regret to have to record the loss by death of two Honorary Members and seventeen Fellows.

Samuel Barker, M.D.	elected	Nov.	21, 1866.
Robert Barnes, M.D., F.L.S.	„	Apr.	20, 1887.
Professor Wilhelm von Bezold (Hon. Member)	„	May	18, 1892.
John Howard Worthington Biggs	„	Nov.	19, 1902.
Joseph Broome, J.P.	„	Dec.	18, 1896.
Alexander Buchan, M.A., LL.D., F.R.S. (Symons Medallist)	„	Dec.	17, 1902.
Patrick Doyle, F.G.S.	„	Dec.	18, 1878.
John Farrah, F.L.S.	„	Apr.	18, 1894.
Joseph Groves, B.A., M.D., F.G.S.	„	Jan.	18, 1888.
Admiral John Pearse Maclear, F.R.G.S.	„	Feb.	16, 1881.
Thomas Henry Goodwin Newton, M.A.	„	Nov.	17, 1880.
William Oelrichs	„	May	18, 1881.
John Montague Phillpott	„	Dec.	20, 1905.
John Byrne Power, M.R.C.P.I., D.P.H.	„	Dec.	18, 1901.
Simpson Rostron, J.P.	„	Feb.	18, 1880.
Henry Chamberlaine Russell, B.A., C.M.G., F.R.S.	„	Nov.	18, 1874.
Dr. Maurits Snellen (Hon. Member)	„	Jan.	17, 1894.
Lieut.-Gen. John Sprot	„	Dec.	20, 1899.
Lawrence Charles Hills Young	„	May	16, 1906.

APPENDIX II.

INSPECTION OF STATIONS, 1907.

All the western and south-western stations have been inspected, and were found to be in a generally satisfactory condition. The number of thermometers tested has been 220, in 21 of which changes of zero had occurred. One rain-measuring glass was found to be defective.

At two stations the whole of the bulb of the wet thermometer was thickly covered with an incrustation of lime. I have occasionally seen a slight deposit on the bulbs at other stations, but never anything like that on these two

thermometers. On comparing these instruments in water along with the other thermometers, I was greatly puzzled to find that they were reading 0°·5 and 0°·8 too low respectively. On the first occasion I was not able to remove the incrustation. On the second occasion, however, I succeeded, by scraping it with a penknife and by means of sulphuric acid, to completely remove it, when the thermometer resumed its proper reading. I am at a loss to account for the fact that the thermometer read too low owing to the incrustation round the bulb, but it points very strongly to the urgent necessity of every observer taking care to see that his wet bulb thermometer is kept perfectly clean and in good condition.

I occasionally experience some difficulty with the Phillips' maximum thermometer, as it is apt to read higher when hung horizontally than when held vertically. In some instruments the detached portion of mercury forming the index may run up the tube to the extent of fully 1° or more. It would be an advantage if the instrument makers would arrange for the air speck not to expand unduly, and so force the detached portion of mercury farther along the tube than to the position indicating the actual temperature at the time.

WM. MARRIOTT.

October 15, 1907.

NOTES ON THE STATIONS.

ABERYSTWITH, *July* 16.—The thermometers, etc., were, as before, in a small railed-off enclosure in the Castle grounds. A larger enclosure was authorised by the Corporation some time ago, but it has not been carried out. The rainfall record must be too small. That recorded in Dr. Thomas's garden in the North Parade is more nearly representative of Aberystwith. A Campbell-Stokes recorder was set up at the beginning of last year. The ball was not in the centre of the frame, being too high. A church tower on the east-south-east makes an angle of 7½° and the old Castle on the south-south-east an angle of 15°. As the cards in the sunshine recorder were liable to shift in strong winds, I recommended that they be held in the frame by clips. The vernier of the barometer had a tendency to slip down.

ARDGILLAN, *July* 20.—This station was in good order. Captain Taylor has an interesting set of earth thermometers, ranging from 1 to 12 feet. I tested altogether seventeen thermometers.

ASHBURTON, *September* 2.—On comparing the thermometers it was found that the dry bulb had gone up 0°·2. The maximum thermometer, when placed horizontally, read 1° higher than when placed vertically; so it has been considered desirable to make a supplementary correction for that amount. Mr. P. F. S. Amery died July 27. His brother, Mr. J. S. Amery, is continuing the observations.

BATH, *August* 13.—I suggested that the legs of the thermometer screen should be strengthened in order to prevent shaking in windy weather. The water receptacle for the wet bulb was imbedded in an outer receptacle which was filled with stearine wax, in order to prevent the water freezing in winter time. The outside of the glass bottle in the 8 a.m. rain gauge was also covered with stearine wax. As the large hotel on the east of the Guildhall cut off some of the morning sun, a new Campbell-Stokes recorder was obtained and mounted on the top of a lamp-post at the Alexandra Park, which is at the summit of a hill on the south of Bath, about 500 feet above sea-level. The exposure is free and open. The ball was not quite in the centre of the frame, being too high.

On comparing the thermometers, it was found that the 4-feet earth read 0°·8 too high.

BELMONT, *August* 20.—The grass minimum thermometer was out of order owing to the column of spirit being much broken up. This I set right. I recommended that some trees near the rain gauge should be topped. The station was otherwise in good order.

BLACKPOOL, *July* 30.—On measuring the chain and tube of the earth thermometer, I found that the bulb was at a depth of 3 feet instead of 4 feet. The top of the tube was 1 foot above the ground. I recommended that at the end of the year the tube should be driven down to 4 feet. The frame of the sunshine recorder was not quite level. Apparently the wooden structure on which it is mounted had warped owing to weather changes. The thermometer screen required painting. Dr. Coutts has had a small embankment made outside the railed enclosure, about 2 feet high on the south-west side, in order to break the force of the wind. The anemoscope and pressure-tube anemometer appeared to be all right. The mercury in the cistern of the Fortin barometer had become dirty and needed cleaning.

CAHIR, *July* 22.—The minimum thermometer had about 1°·5 of spirit up the tube. The instruments otherwise were in good condition. The observations are now taken by the gardener.

CASTLE HILL, FILLEIGH, *August* 24.—A Fortin barometer has been obtained since my last visit. The Glaisher rain gauge has a shallow funnel. I recommended that four holes be made in the inverted flange round the gauge, in order to drain off the water and so prevent its insplashing when the funnel was taken off.

CHELTENHAM, *August* 16.—The enclosure for the instruments has been made much larger, and light railings substituted for the thick high railings. On comparing the thermometers it was found that the minimum had gone up 1°·0. The grass minimum had a little spirit up the tube. A Campbell-Stokes sunshine recorder had recently been obtained, and it is placed on the summit of the dome of the pavilion in the Pitville Gardens. The ball was not quite in the centre of the frame, but this I adjusted. The rain-measuring glass was not correct, and I recommended that a new one be obtained forthwith.

CHESTER, *July* 25.—At the beginning of the year the Rev. J. C. Mitchell handed over his instruments to the Chester Corporation in order to secure the continuance of the observations. It was the intention to have the instruments placed in the Grosvenor Park, but difficulties arose which prevented this being carried out. Failing any other suitable site, Mr. Mitchell ultimately had the instruments put up at the Sewage Purification Works. The site is exceptional, being on the ground between two large concrete tanks. The conditions are therefore hardly natural. The only other suitable site close by is on lower ground ; but this is a few feet below high-water mark, and so might be flooded at times. The observations are taken by Mr. Scouller. I gave him instructions in the method of observing. The grass minimum had a considerable amount of spirit up the tube.

CULLOMPTON, *September* 4.—There was no change in the thermometers. The grass minimum had a little spirit up the tube. The sunshine recorder appeared to be in adjustment. As some trees have grown up in a neighbouring garden, and might possibly slightly affect the winter sunshine in the morning and evening, I recommended that they be topped, if permissible.

DUBLIN, *July* 19.—The instruments were in the same position as at my last visit. On comparing the thermometers it was found that the maximum

had gone up 0°·3. Trees on the east and north-west required cutting back. Sir John Moore is a very keen observer, and has made the best of the limited space at his disposal.

DUBLIN (TRINITY COLLEGE), *July* 19.—The thermometer screen required painting. The grass minimum had about 1°·5 of spirit at the top of the tube. The ball of the sunshine recorder was not quite in the centre of the frame, being too near the eastern side. The trees on the west evidently cut off some of the evening sun.

FALMOUTH, *August* 31.—The minimum thermometer had 1°·0 of spirit up the tube. Otherwise the instruments were all in good order.

GWERNYFED PARK [BRECON], *August* 20.—The wet bulb was not working properly, the muslin being dry and the conducting thread too thin. I explained how to keep the muslin and thread in good order. The minimum apparently had a little spirit at the top of the tube. The pipe of the rain gauge was broken off the funnel. The thermometer screen required strengthening and painting.

HAVERFORDWEST, *August* 21.—The grass minimum had some spirit up the tube. The rain gauge required a little soldering. A new Campbell-Stokes sunshine recorder had been obtained, and was in good adjustment. Birds have so frequently interfered with the ball and card that Mr. Phillips has been obliged to put a wire protection over the recorder to keep the birds off. I found that the amount of sunshine had been measured with the top of another card instead of along the actual burn.

HOYLAKE, *July* 26.—The grass minimum had a bubble of air in the column of spirit. I pointed out that the muslin on the wet bulb should fit tight round the bulb.

ILFRACOMBE, *August* 22.—On comparing the thermometers it was found that the minimum had gone up 0°·2. The pipe at the bottom of the funnel of the rain gauge had been broken off.

KILLERTON [EXETER], *September* 4.—The wet bulb had a thick incrustation of lime all round the bulb. On comparing the thermometer I found that it was 0°·8 too low. After removing the incrustation by means of sulphuric acid and by scraping it with a penknife, the thermometer resumed its proper reading. The rain gauge in use is the Crosley registering pattern, the funnel of which is 10 inches square. I recommended that a Snowdon gauge be obtained before the end of the year.

KINGSTOWN, *July* 23.—The instruments were in good condition. Since my last visit the screen has been raised so that the thermometers are now four feet above the ground, and the glass has been taken out of the door of the screen and louvering put in. I suggested that the inside of the screen should be washed and painted white. The observations are taken by Mr. Mason, the park curator, but Dr. Power takes the cloud observations. I did not test the instruments, as Mr. Lempfert was to inspect the station for the Meteorological Office in the course of a few days. The maximum and minimum thermometers are strapped up to prevent vibration in wind. [Dr. Power died a few weeks after my visit. See p. 136.]

LECHLADE, *September* 16.—Mr. Metcalfe in September 1906 removed from Roche Court, Winterslow, to Claydon House, Lechlade. The ground is flat, being in the Vale of Whitehorse; the river Thames is about half a mile to the south. The instruments are well exposed. The tube of the maximum thermometer was liable to slip down, so I wedged it up with cork. Owing to the difficulty of finding a suitable place for the Campbell-Stokes sunshine recorder, it has not been found advisable to take any records of the sunshine.

The 1-foot earth thermometer was found to be only at the depth of nine inches, I recommended that the tube be driven three inches farther into the ground.

LLANDUDNO, *July* 24.—On comparing the thermometers it was found that the minimum had gone down 0°·2. The cylinder of the rain gauge had apparently been knocked several times when the grass was cut, and so the funnel was difficult to take off. I suggested that it be made to fit on easier. The sunshine recorder appeared to be in adjustment, but there was no sun at the time of my visit. I suggested that clips be used to keep the cards fixed, as birds occasionally peck at the ends of the cards. The young man who had been assisting with the observations for some time had recently left, so a new deputy had been taken on.

LLANERCHYMEDD, *July* 18.—The instruments were in the same position as previously. I requested that more attention be given to the wet bulb in frost, and also that the thermometers be read to tenths of a degree. On comparing the thermometers it was found that the maximum now reads 0°·1 too high, and the minimum is 0°·4 too high.

MALMESBURY, *August* 12.—The instruments were in good order. I suggested a different arrangement of the water receptacle for the wet bulb, and urged the observer to read the thermometers to tenths of a degree.

MALVERN, *August* 17.—I recommended that the maximum thermometer be hung more inclined, in order to prevent the mercury jumping up the tube when placed on the screen after being set. The legs of the thermometer screen required strengthening in order to prevent vibration in wind. I suggested that a creeping plant near the rain gauge should be cut back.

MIDHURST, *August* 8.—As it was proposed to establish a meteorological station at the King Edward VII. Sanitorium, I went down on this day and set up the instruments. They are placed on a lawn on the south of the building and have a good exposure. The height is 480 feet above sea-level.

NEWQUAY, *August* 30.—The thermometer screen required strengthening to prevent vibration in wind. The rim of the rain gauge required soldering on to the funnel. The sunshine trace was not running parallel with the card, as the ball was not in the centre of the frame of the recorder. I tried to remedy this by endeavouring to shift the pedestal, but this was not sufficient. I pointed out to Dr. Vigurs how the frame might be unscrewed and readjusted, so as to bring the ball into the centre.

NORTHWICH, *July* 26.—I recommended that the maximum thermometer be mounted a little more on the incline, to prevent the mercury running up the tube. As there is a great deal of smoke and other impurity in the air, I recommended that the thermometers be occasionally washed.

PENZANCE, *August* 29.—The thermometer screen required painting, and the rain gauge needed a little soldering. The Campbell-Stokes and the Jordan sunshine recorders seemed to be in good adjustment.

PORTHCAWL, *August* 14.—The mercury in the maximum thermometer seemed to have a tendency to run up the tube, so I recommended that it be mounted more on the incline. I urged that the muslin and cotton on the wet bulb be changed more frequently. The band of the Glaisher rain gauge had parted company at one place with the funnel, and so extra rain was liable to run into the bottle below. I recommended that it be re-soldered, and also that holes be made in the flange to drain off the water.

PRINCETOWN, *August* 28.—On comparing the thermometers it was found that the minimum had gone down 0°·3. The barometer was not hanging quite vertically. It had been moved since the last inspection to make room for the telephone instrument. I gave the observer instructions as to the measurement of snow. A new building will shortly be erected in the Infirmary grounds, not far from the instruments.

RODEN, *July* 15.—On comparing the thermometers it was found that the dry bulb had gone up 0°·1, and the maximum 0°·2, and that the minimum had gone down 0°·3. Small apple trees had been allowed to grow up close to the thermometer screen and rain gauge. I recommended that the screen and rain gauge be moved to a more suitable and open situation. I requested that more attention be paid to the working of the wet-bulb thermometer. The board on which the Fortin barometer was suspended was not fixed at the bottom, and so was liable to get out of the perpendicular without being noticed.

ROSS, *August* 19.—The bulb of the wet thermometer was completely covered with a thick incrustation of lime. I endeavoured to remove this, but was not successful. I therefore recommended that some acid be used for the purpose, and that the thermometer should always be kept clean. The thermometer had apparently gone down 0°·5. I recommended that some trees round the rain gauge be topped.

ROUSDON, *September* 5.—This station was in good order. The ball of the sunshine recorder was not quite in the centre of the frame. This I readjusted. The trees on the estate have grown very considerably since my last visit. Some trees on the south-west and west-south-west of the sunshine recorder make an angle of 7°, and so may cut off some of the afternoon sun in the early spring and late autumn.

RUMNEY, *August* 14.—This station was in good order. The spare maximum thermometer had an air speck in the column of mercury in addition to the index speck. When held in an upright position the thermometer read low, but when placed in a horizontal position, it seemed to read high.

RUTHIN, *July* 25.—The base of the sunshine recorder required fixing in order to keep the instrument always on the meridian. The hills and trees on the east cut off the early morning sun, as they form a considerable angle.

SALCOMBE, *August* 27.—The observations are now taken by Dr. Twining, the instruments having been removed to his garden, where there is a good exposure. They are nearly 30 feet higher than at the previous station. The minimum had 1° of spirit up the tube. The water receptacle was much too close to the bulb of the wet thermometer. I recommended a readjustment of the thermometers in the screen. The ball of the sunshine recorder was not quite in the centre of the frame. This I readjusted, and explained how the sunshine should always be measured along the actual burn on the card.

SIDMOUTH, *September* 6.—The minimum thermometer had 1° of spirit up the tube. Trees on the east cut off a little of the early morning sunshine from the Jordan recorder.

SOUTHPORT, *July* 29.—Everything at this station was in good order. The numerous self-recording and other instruments are kept at a high state of efficiency. A second Campbell-Stokes sunshine recorder has been obtained, and the results agree very closely with those from the other recorder. The Jordan sunshine recorder has been discontinued.

TEIGNMOUTH, *September* 3.—The grass minimum thermometer had recently been broken, and the new one—hollow cylinder pattern—read 0°·3 too high. A wire cage is put over the radiation thermometers to protect them from being broken by stones thrown into the enclosure. The water receptacle was too high, and so permitted the conducting thread to siphon out the water. The board on which the Fortin barometer was suspended required fixing at the bottom to prevent it being shifted out of the vertical. The Campbell-Stokes sunshine recorder is mounted on the ridge of the roof of the lifeboat house. The exposure is good. The flagstaff, however, on the west-south-west may perhaps very slightly affect the record. The ball was not quite in the centre of the frame.

TORQUAY, *September* 3.—On comparing the thermometers it was found that the maximum had gone down 0°·5. There was a considerable difference between the readings of the thermometers when placed vertically and when placed horizontally. The Campbell-Stokes sunshine recorder appeared to be in good adjustment.

TOWYN, *July* 17.—As Mr. Harries, from the Meteorological Office, had inspected this station the previous week, I did not test any thermometers except the 3-feet earth, which appeared to be all right. The ball of the sunshine recorder was not quite in the centre of the frame, being a little too forward. Dr. Lloyd has a percolation gauge with grass top.

WAKEFIELD, *March* 14.—I called to see Dr. French, as the maximum and minimum thermometers had not been working properly. I found that the air bubble of the maximum had got into the bulb, so that the instrument was acting as an ordinary thermometer. In the minimum an air bubble had got into the column of spirit. I arranged for new thermometers to be sent, which were put into position, and I explained the method of their working. I learned that owing to increased duties at the Prison it had not been possible for the observations to be taken at 9 p.m., but that they had been taken at 8 p.m.; also, there were five warders taking the observations when on duty, so efficiency was reduced. I saw Dr. Clarke, the medical officer, who agreed to speak to the Governor with regard to permission being obtained for the night warder to take the observations at 9 p.m. as formerly.

WESTON-SUPER-MARE, *August* 15.—On comparing the thermometers I found that the minimum had gone down 1°·0, and that the grass minimum read 2°·5 too low. The mercury in the maximum at low temperatures has a tendency to run up the tube a little when set. I recommended that the thermometer be hung more on the incline. The sunshine recorder appeared to be in adjustment. A church spire on the east-south-east cuts off the sun in the morning, and the church tower on the west and west-north-west cuts off a little sunshine in the evening in the summer.

WHITCHURCH, TAVISTOCK, *August* 26.—This station was in good order. On comparing the thermometers it was found that the dry had gone up 0°·1, and the 6-inch earth 0°·2.

WOOLACOMBE, *August* 23.—The tube of the maximum thermometer was loose and liable to slip down. This I fixed with some cork. The funnel of the rain-gauge required soldering. The barometer was not hanging quite perpendicularly. This I adjusted by putting a wedge at the back of the board at the top. The sunshine recorder seemed to be in good adjustment. The hills on the east-north-east make an angle of 7°, and those on the south-east an angle of 8°. I recommended that the sunshine cards should be measured to tenths of an hour.

APPENDIX III.

OBITUARY NOTICES.

ROBERT BARNES was a son of Philip Barnes, founder of the Royal Botanical Society of London, and was born at Norwich on September 4, 1817. He came of an old Norfolk family, for many years owners of Cromer Hall, and one of his ancestors, a namesake Robert Barnes, suffered death by burning during the Marian persecution.

At the age of nine he went with his brother Philip to school at Bruges, where he remained for several years, leaving at the outbreak of the revolution which separated Belgium from the kingdom of the Netherlands in 1830. When 15 years of age he was apprenticed to Richard Griffin, founder of an association of poor-law medical officers, and surgeon to the Old Men's Hospital, Norwich.

In due course he proceeded to University College, and received the diploma of M.D. Lond. in 1848. He also studied at St. George's Hospital and, after qualification, in Paris. He was made a Fellow of the Royal College of Surgeons by election in 1883, whilst he was for many years intimately associated with the College of Physicians. In 1859 he was elected a Fellow. In 1873 he delivered the Lumleian Lectures on Convulsive Diseases of Women.

After qualifications Dr. Barnes practised for several years at Notting Hill. His taste for obstetrics was developed early. For a time he lectured on midwifery at the Hunterian School of Medicine, and he became Obstetric Surgeon to the Western General Dispensary, and, after holding other small appointments, was elected Assistant Obstetric Physician at the London Hospital, where he had the honour of succeeding Ramsbotham in the senior appointment. He transferred himself later on to St. Thomas's Hospital, and, lastly, ended his hospital career as Obstetric Physician at St. George's.

Dr. Barnes took a prominent part in the foundation of the Obstetrical Society, and in 1884, with the co-operation of his son, Dr. Fancourt Barnes, he issued a two-volume work on *Obstetric Medicine and Surgery*. He died on May 12, 1907.

He was elected a Fellow of this Society on April 20, 1887, and served on the Council from 1893 to 1897, being Vice-President in 1894-1895.

JOHANN FRIEDRICH WILHELM VON BEZOLD was born at Munich on June 21, 1837, and was admitted to the degree of Ph.D. at Göttingen in 1860. Thence he returned to Munich as a privat-docent in 1861, became extraordinary Professor of Physics in the University in 1866, and ordinary Professor at the Polytechnic in 1868. In 1878 he undertook the organisation of the Bavarian meteorological service as Director of the Central Meteorological Station. He remained in charge of this service until 1885, when he was called to Berlin as Professor of Meteorology in the University, and Director of the Meteorological Institute, which was reorganised by him. The Institute included not only the central establishment in Berlin, which formed the headquarters of the branch for dealing with the climatology and rainfall of the Prussian kingdom, but also the meteorological and magnetic observatories at Potsdam, and later the aeronautical section at Tegal.

In the course of his long and distinguished scientific career Dr. von Bezold's activity ranged over a wide field. His writings include papers on colour vision and the retina, and the dust figures of electrical discharge; but he is best known for his contributions to meteorology on the physics of the atmosphere, the aspect of the subject which he found most attractive, and to the theory of terrestrial

magnetism. A volume of his collected papers on these subjects was published in 1906.

He died on February 17, 1907.

He was elected an Honorary Member of this Society on May 18, 1892.

JOHN HOWARD WORTHINGTON BIGGS was the son of William Biggs of Leicester. He travelled in the East and West, and collected numerous mementoes, etc. He was greatly interested in observations of rainfall and sunshine in the Lake District, where he resided for part of every year.

In 1905 he published a large coloured diagram illustrating the average weather at Bowness on Windermere, based on astronomical and meteorological data, 1883-1902; and also another diagram entitled "Holidays and Rain." This was prepared with the object of inducing visitors to the Lake district to take their holidays earlier in the year than is the present custom, so as to avoid the heavier rainfall of the late summer and autumn.

He died suddenly on June 1, 1907, aged 65 years.

He was elected a Fellow of this Society on November 19, 1902.

JOSEPH BROOME was born on May 1, 1825, at Reston Brook, near Fredsham. When sixteen years he entered the service of Messrs. Pemberton and Savage, Manchester, who were then engaged in the dyed goods trade. A little later he took a situation with Messrs. Samson and Lennox, merchants and shippers, and eventually was admitted a partner of that firm.

In 1881 Mr. Broome was asked by the Manchester Chamber of Commerce, and agreed to represent at the French Treaty Inquiry the department of dyed and printed satins, twills, cambrics, and other descriptions of linings; and, in co-operation with the late Sir Henry Mitchell, the velvet trade, cords, and silk velvets. In the same year he was appointed a magistrate for Manchester, and in 1891, after he had lived a few years at Llandudno, he was nominated High Sheriff of Carnarvonshire. He served on the Manchester Board of Overseers, was a vice-president of the Manchester Athenæum, and for ten years was the president of the Graphic Art Club. He was also for some time one of the directors of the Union Bank of Manchester. In 1885 he founded the firm of Broome, Hallwork, and Foster, which still exists as Broome and Foster.

For nearly the whole of his long life Mr. Broome was an exceptionally active business man, but he always found time enough to devote to a great deal of public work. Much of it was of a kind that is not always recognised most prominently—quiet but useful movements in various directions for the betterment of all sorts of conditions of living. He was, too, associated with several important commercial organisations at Manchester. He was a director of the Royal Exchange, and nobody took a keener interest than he in the development of the Royal Botanical Gardens at Old Trafford, especially in the days when they were estimated at their highest value for the purpose of flower culture.

Mr. Broome was a real lover of flowers, and he tended his own garden in the way that can only be done by a gardener who has what amounts to an almost instinctive knowledge of flower-life. When he lived at Didsbury, and afterwards on his settlement at Llandudno, his garden was the chief source of his pleasure.

He died on January 25, 1907.

He was elected a Fellow of this Society on December 18, 1896.

ALEXANDER BUCHAN was born in Kinnesswood, Kinross, on April 11, 1829, and was educated at the Free Church Normal School in Edinburgh, then newly founded as a result of the Disruption of 1843, and afterwards at the University, where he took the degree of M.A. in 1864. From 1848 onwards he followed the profession of a teacher, for which indeed he was naturally gifted, and

throughout his life he retained the power of imparting instruction easily and pleasantly. As a schoolmaster he filled appointments at Banchory, Blackford, and lastly at Dunkeld. But for a weakness in the throat that continued to trouble him through life he might never have relinquished the profession he had chosen.

The first scientific study which attracted the attention of Alexander Buchan appears to have been botany, and especially the study of the native plants of Scotland, though he took part in at least one of the long excursions to the Alps which Professor Balfour led through all the difficulties of continental travel at that period. The field botanist cannot but be interested in the weather, and we may assume that it was in this way that Buchan's thoughts were turned to meteorology.

The Scottish Meteorological Society was founded in 1855, and its early records give full particulars of the qualifications, appointment, and withdrawal of successive Secretaries; but, curiously enough, nothing is said in the published minutes of the retirement of Mr. A. H. Burgess, who was in office at the meeting on September 3, 1860, or the appointment of Mr. A. Buchan, who read a paper as Meteorological Secretary at the meeting of April 11, 1861. The subject was the cold weather of the previous Christmas, and this, so far as I can ascertain, was Dr. Buchan's first contribution to the literature of meteorology. It is interesting to observe that even at this early period he treated the problem in a distinctly geographical manner, and he called attention to a fact, the importance of which he often referred to afterwards, the remarkable difference in the distribution of low temperatures according to the configuration of the surrounding land surface. The paper concludes: "Thus the highest winter temperature is to be found along the west coast; the lowest in low plains at such a distance from the sea as not to be influenced by it, and in hollows enclosed by hills; and all places elevated above the immediately surrounding neighbourhood are effectually protected from the extremes of temperature."

Throughout his life Dr. Buchan always insisted on the importance of taking the character of the site of a station into account before using its record in drawing any general conclusions as to climate. It is not surprising that he became an original member of the Royal Scottish Geographical Society, and took a constant interest in its welfare.

From 1861 onwards Dr. Buchan was nearly as much the author as the editor of the *Journal of the Scottish Meteorological Society*, the "new series" of which was started in the following year. He spent much time on the discussion of barometrical observations during the early years at the Society, dealing at first with the records for Scotland, but soon passing on to consider the data for the whole world. It was the period of most rapid advance in meteorology; the principles of the synoptic weather chart, of the relation of wind direction to the isobars, and of scientific forecasts of the weather for short periods, had just been enunciated, and, thanks to the enthusiasm with which Buchan took the matter up in these early years, the name of Buys Ballot and the extension of the relation between barometric gradient and wind direction were soon thoroughly familiar in this country.

In 1867 he published his *Handy Book of Meteorology*, a second edition of which appeared in the following year. This book showed so firm a grasp of the principles of the science, and so thorough a mastery of observational detail, that it became the standard text-book in the language, and in later years many were the appeals made to the author to bring it up to date; but the increasing volume of official work and the burden of various important researches were such that the appeals had to be made in vain. In one way it is perhaps better that the book should remain as a landmark of the meteorological knowledge of forty years ago, for the time has now passed in which it might have been possible

to adapt the frame for the picture of that day to the ampler canvas of the present. Following on the larger work an *Introductory Text-book of Meteorology* in 1871 presented no new features.

In 1869 Dr. Buchan read to the Royal Society of Edinburgh the paper by which his reputation as a leader in meteorology was established at once and for ever throughout the world. It dealt with a subject of such difficulty and complexity that only an enthusiast in the marshalling of figures could ever have attempted it with any prospect of success—no less a problem than the charting of the mean distribution of atmospheric pressure and of prevailing winds over the globe. This paper was perhaps the most fruitful, though it was far from being the most laborious piece of work which Dr. Buchan accomplished. A natural result was that on the return of the *Challenger* expedition in 1876 the vast mass of meteorological data accumulated in every part of the world was handed over to Dr. Buchan to report upon. Following the enlightened practice introduced for all the reports of that great expedition, additional data accumulated before and after the expedition were utilised, and so Dr. Buchan was able to prepare as the basis of his *Report on Atmospheric Circulation*, published in 1889, maps of the world representing the mean temperature, and also the mean barometric pressure and wind directions for every month as well as for the year. These entirely original maps went far towards forming a meteorological atlas, and when only a few years ago Dr. Buchan, in association with Dr. Herbertson, undertook the editorship of the volume on meteorology in Bartholomew's great *Physical Atlas*, the data compiled for the *Challenger* Report formed one of the most striking advances on the Berghaus *Atlas* upon which it was based.

Oceanography occupied a considerable share of Dr. Buchan's attention. At an early period he had organised observations of sea-temperature in connection with herring fisheries, and in later years he contributed a massive memoir on *Oceanic Circulation* to the *Challenger* Reports.

Climatology, that department of meteorology which is equally a department of geography, always claimed the lion's share of Dr. Buchan's attention. He worked as much with maps as with tables of figures, and it is to his patient labours that we are indebted for most of our knowledge as to the monthly distribution of pressure and temperature over the British Isles.

The relation of climate to disease occupied his attention, and was dealt with in several papers written jointly with Sir Arthur Mitchell, one of the founders of the Scottish Meteorological Society.

In 1883 two important enterprises engaged much of the time of Dr. Buchan; one of these was the establishment of the Scottish Marine Station at Granton by Sir John Murray. It was at this time that I was brought into close relations with Dr. Buchan, and in the instructions I received from him in the art of meteorological observing, I first recognised his vast experience and technical skill, and experienced that kindly helpfulness which never ceased to the end of his life.

The second enterprise was the foundation of the Observatory on the summit of Ben Nevis, and subsequently of a second Observatory at Fort William. For the remainder of his life the meteorology of Ben Nevis unquestionably held the first place in Dr. Buchan's scientific work. He took his share in the efforts to awaken public interest and secure the necessary funds to start the Observatories, and to carry them on; and he put forth more energy than was perhaps prudent from the point of view of health in the effort to persuade an indifferent Government to place the work on a permanent basis. This is not the place to revive the memory of old controversy, or to rake up old grievances, but without stirring the ashes of the old fires, it may be said that although the departmental committee appointed by the Government at the instance of Dr. Buchan and his

colleagues failed to provide for the continuation of the work he had so much at heart, it did at least make recommendations of a kind which opened the way for great improvements in the conditions of meteorological work, and in the useful co-operation of the various meteorological agencies in the United Kingdom. The publication of the hourly observations at the two observatories and the discussion of the data filled his later years, and although comparatively little remained to be done, Dr. Buchan died before the completion of the last volume.

While Dr. Buchan was particularly associated throughout his long and active life with the scientific activity of Scotland, and of Edinburgh in particular, he was also well known in London, where he had a place on several important representative bodies. For many years he was the representative of the Royal Society of Edinburgh on the Committee, nominated for the most part by the Royal Society of London, for the administration of the Government grant of £4000 per annum for scientific research. In 1887 he was appointed a member of the Meteorological Council, the body which, on the responsibility of the Royal Society of London, directed the Meteorological Office and administered the sum set apart by Parliament for the meteorological service of the country. Dr. Buchan also frequently attended the meetings of international committees, and was personally acquainted with all the leading continental authorities in his own department.

When the Symons Memorial Gold Medal was founded, the Royal Meteorological Society made the first award to Dr. Buchan as the most eminent British meteorologist.

Dr. Buchan received the honorary degree of LL.D. from the University of Glasgow in 1887. He was elected a Fellow of the Royal Society of Edinburgh in 1869, a member of its council two years later, and he received in turn the Makdougall Brisbane and the Gunning prizes of the Society. In 1878 he became curator of the library, a post which, with the permanent membership of the council, he held until within a year or two of his death. In my mind, and in the minds of many who frequented the meetings of the Royal Society of Edinburgh, in the 'eighties and 'nineties of last century, the old rooms on the Mound will always remain most intimately associated with three notable figures —Professor P. G. Tait, for so many years the general secretary, Dr. Alexander Buchan, and Mr. James Gordon, the picturesque librarian. In connection with the Royal Society Club, Dr. Buchan shone in a sphere with which many to whom he was familiar in the streets and in his office never associated him, the purveyor of intellectual gaiety of the old Scottish type. As a host Dr. Buchan was always charming, and his breakfasts on the occasion of such meetings as those of the British Association are not to be forgotten by anyone who had the privilege of taking part in them. Mrs. Buchan amply seconded his hospitality, and the guest who came even for an hour could not fail to recognise a domestic life of singular harmony. Nor can we close these notes without a tribute to the memory of Miss Jessie Hill Buchan, the faithful niece and invaluable assistant who worked for so many years in the office with her uncle; and it is sad to remember that both wife and niece passed away before himself. He is survived by Dr. Hill Buchan, his only son.

In private life Dr. Buchan was full of surprises to those who expect to find a student of science a man of one idea. He took a deep interest in Church matters, and was an elder in Free St. George's. He revelled in poetry, especially in the old Scottish ballads, from which on suitable occasions he could produce singularly apt quotations. He was a firm and generous friend, and all his qualities were such as to enshrine him in the memory of those who knew him in the full vigour of his strenuous years as something grand and heroic cast in the mould of Browning's "Grammarian":—

Here—here's his place, where meteors shoot, clouds form,
Lightnings are loosened,
Stars come and go! Let joy break with the storm,
Peace let the dew send!
Lofty designs must close in like effects:
Loftily lying.
Leave him—still loftier than the world suspects,
Living and dying.

[The above memoir was written by Dr. H. R. Mill, and is reprinted from the *Scottish Geographical Magazine*, 23, p. 427.—EDITORS.]

Dr. Buchan, who died on May 13, 1907, was elected a Fellow of this Society on December 17, 1902.

A portrait of Dr. Buchan was given in the *Quarterly Journal*, Vol. 28.

JOHN PEARSE MACLEAR was born in 1838 at the Royal Observatory of the Cape of Good Hope, his father, Mr. (afterwards Sir Thomas) Maclear, being at that time Astronomer-Royal there. He was privately educated, and showed a marked ability in mathematics and a strong desire to join the Navy. In 1851 he was appointed naval cadet and joined the *Castor*. He served as midshipman in the *Algiers* from 1854 to 1856 during the Crimean War, both in the Baltic and the Black Sea. He was sub-lieutenant in the *Cyclops* in the Red Sea at the time of the troubles at Jeddah in 1858; and during the China War and the taking of the Taku forts he was serving as lieutenant in the *Sphinx* from 1860 to 1862. He then qualified as gunnery-lieutenant, and was appointed 1st lieutenant to the *Octavia*, and served in her during the Abyssinian War in 1868, after which he was promoted to commander, and had a longer interval on shore, which was devoted to studies in various subjects, including languages and magnetism. This time also he made a walking tour in Norway with his lifelong friend Prof. Alexander Herschel,[1] whose sister he subsequently married (in 1878). He then eagerly seized the opportunity offered to him of joining in the "Total Eclipse" expedition organised by Prof. (afterwards Sir Norman) Lockyer to India in December 1871.

In 1872 the *Challenger* was fitted out for her famous dredging and sounding voyage round the world, and he was selected as her commander under Captain (afterwards Sir George) Nares; and throughout that expedition he took the keenest and most ardent interest in all the important work carried on by Sir Wyville Thomson and his scientific staff, he himself sharing in the work of magnetical observations. The experience gained during that memorable voyage added considerable value to his own later work in the Survey Service, to which he subsequently devoted the rest of his time as captain—first in the *Alert*, from 1879 to 1882, surveying in the Straits of Magellan and the great Barrier Reef of Australia, and, secondly, in the *Flying Fish* surveying ship in China, Korea, and the Eastern Archipelago, from 1883 to 1887.

He was then promoted to rear-admiral, and retired from active service, and took up the arduous work of compiling *Sailing Directions* under the direction of the distinguished hydrographer Admiral Sir William Wharton, doing much valuable work up to the very end of his life. He was engaged on his seventh volume of these *Sailing Directions*, which was for the waterways and great lakes of Canada, when, on July 17, 1907, sudden death overtook him at Niagara Falls.

While living in his quiet country home at Chiddingfold in Surrey he was

[1] Professor Herschel, F.R.S., passed away a month before his brother-in-law, at Slough, on June 18, 1907. Some of his contributions upon meteorological topics are contained in the *Quarterly Journal* of the Society. He attended (though then in a critical state of health) the May meeting in 1907, and his remarks on that occasion regarding the fall of a meteorite will be found in the *Quarterly Journal*, 33, p. 282.

a close observer of meteorological occurrences, and was at all times an ardent lover of nature and a warm advocate for the protection of birds.

Admiral Maclear was elected a Fellow of this Society on February 16, 1881, and served on the Council in 1883, and from 1889 to 1898, being Vice-President in 1890-91.

JOHN MONTAGUE PHILLPOTT died on July 17, 1907, after an illness of four months, at the age of 34. He was an assistant in the office of the Royal Meteorological Society from February 1889 till October 1899, when he left, at the invitation of Mr. Symons, to assist him in the office of British Rainfall. He remained there, serving under Mr. H. S. Wallis and Dr. H. R. Mill respectively, until the time of his death.

Mr. Phillpott was quick and accurate in his computations, and rendered valuable assistance in both the offices in which he was engaged.

He was elected a Fellow of this Society on December 20, 1905.

DR. JOHN BYRNE POWER was born in Dublin in 1834, and was the eldest son of James Power, of Hazelbrook, Rathfarnham, Co. Dublin. In early life he suffered greatly from delicate health, and being at that time of independent means did not enter upon a professional career until somewhat advanced in years. At first he studied law, but his taste did not lie there, so later on he entered the medical profession. Delicate as he was, he possessed remarkable courage and devotedness, and on one occasion stayed on, as resident, in a large hospital crowded with cases of small-pox, while others left in panic.

Soon after he took out his degrees he was appointed senior physician to St. Michael's Hospital, Kingstown, where he had ample opportunities for the scientific pursuit of his profession. During his tenure of office there he carried out elaborate studies and experiments on the subject of the elimination of nitrogen compounds from the blood. His essay on this subject is a model of patient and thorough scientific work and research. In it he proved, for the first time, that the skin has very limited power to carry off these compounds—a fact which has a most important bearing on treatment in many crises of illness.

Dr. Power contributed many valuable essays on medical subjects, *e.g.* "Powers and Duties of Sanitary Inspectors," "The Climate of Kingstown and the South of England compared," "On the Public Health of Kingstown," "Is Drinking Sewage by Milch Cows a Danger to Public Health?" etc.

Of latter years—since his appointment as Medical Officer of Health at Kingstown—Dr. Power devoted himself, heart and soul, to that department, and by his careful records of temperature, winds, and rainfall, showed that the climate of Kingstown is superior in many respects to that of any of the well-known health resorts on the south coast of England.

Dr. Power was a gentleman of wide reading and high culture, an excellent musician, and had travelled extensively; he was of charming personality, genial and amiable to all, and universally beloved. He died on August 30, 1907.

He was elected a Fellow of this Society on December 18, 1901.

SIMPSON ROSTRON was born on April 24, 1833, and was the only son of Laurence Rostron, of Edenfield, Lancashire. He was called to the Bar by the Middle Temple in 1854. He was for many years special pleader on the Northern circuit. He held the Commission of the Peace for the county of Surrey. He was for nearly thirty years a director of the South Metropolitan Gas Company.

Mr. Rostron travelled a good deal in the early part of his life, and was very fond at one time of Alpine climbing. He was a member of the Alpine

Club, and it was during some of these climbs that he began to make observations on the differences in temperatures, etc. He was keenly interested in extremes of heat and cold and their effects. Even up to the end of his life he would always look at the thermometers in the screen twice, if not more, in the day, and if he could not go out, would invariably ask for the weather-book. His excellent memory was most useful in remembering "record" temperatures, etc.

He was the Royal Meteorological Society's observer at Beddington since 1881. He died on November 7, 1907.

He was elected a Fellow of this Society on February 18, 1880.

HENRY CHAMBERLAINE RUSSELL was the son of the Hon. Bourn Russell and was born at Maitland, New South Wales, on March 17, 1836. He graduated at Sydney University in 1858, and was soon after appointed assistant to the Rev. W. Scott, the first Government Astronomer for New South Wales. At the age of 25 he temporarily held this latter post after the death of Mr. Scott, until Mr. Smalley was appointed. On the death of the latter in 1870, Mr. Russell was appointed Government Astronomer, and he held that post for 35 years. He reorganised the Observatory and kept it in an efficient state. He also turned his attention to meteorology.

In 1870 there were twelve meteorological observing stations in the whole state of New South Wales, and the Government could not afford any large contribution towards an increase. Mr. Russell, however, induced the squatters and farmers to make observations of rainfall and evaporation, and, by his mechanical ingenuity, furnished the stations with the necessary apparatus with the smallest possible outlay. In 1876 he had collected all the observations of rainfall made in Australia and discussed them, with the result that he believed that there was a periodicity. In 1878 he had a large number of returns from the observing stations, and after careful analysis was enabled to commence the publication of weather charts in the newspapers. In 1887, in conjunction with Sir Charles Todd of South Australia, and Mr. Ellery of Victoria, he succeeded in establishing a system of weather forecasts.

He also designed several self-recording meteorological instruments, including an anemometer, pluviometer, thermograph, electrical barograph, etc.

Mr. Russell was a member of the Board of Technical Education, and in 1891 was made Vice-Chancellor of the University of Sydney. He was elected a Fellow of the Royal Society in 1886. He was four times President of the Royal Society of New South Wales, and was in 1888 the first President of the Australasian Association for the Advancement of Science. In 1891 he was made a Companion of the Order of St. Michael and St. George. He died on February 22, 1907, in the seventy-first year of his age.

He was elected a Fellow of this Society on November 18, 1874.

MAURITS SNELLEN was born on April 1, 1840, at Zeyst, not far from Utrecht. After visiting the gymnasium at Gouda, he entered the University of Leiden, and devoted himself to the study of mathematics and physics. As a result of this study, he obtained the degree of Doctor of Mathematics and Physics in 1865. From 1863 to 1864 he was a teacher of physics and mechanics at Leiden, then from 1864 to 1867 teacher of physics in the gymnasium at Groningen, and, lastly, from 1867 to 1873 teacher of mathematics at Delft. He then gave up teaching and entered the physical laboratory of the University of Utrecht as assistant to Prof. Buys Ballot, who at the same time occupied the position of Director of the Royal Dutch Meteorological Institute.

Dr. Snellen soon became engaged in meteorological work, especially in the magnetic branch, and so he entered upon his career as meteorologist in 1877 as

director of the first section of the Institute. In this position he remained until 1891, when, after the death of Prof. Buys Ballot, he was appointed chief director. In 1889 he was admitted as private lecturer in meteorology at the University of Utrecht. In 1902 a reorganisation took place and he was appointed director of a newly created section for terrestrial magnetism and seismology. This new position he resigned on November 1, 1905, and then settled down at Apeldoorn, where he died on October 20, 1907, at the age of 67.

Dr. Snellen took a prominent part in the Dutch North Polar Expedition on the *Varna* in 1882-83.

He was elected an Honorary Member of this Society on January 17, 1894.

Lieut.-General John Sprot was born in March 1830. He was educated partly at a preparatory academy for Addiscombe, and partly in Germany. He joined the 83rd Regiment in 1848.

He served with his regiment in India during the Mutiny, and acted as Brigade-Major to a field-force operating in Rajputana, winning the highest praise from his superior, General Roberts. In 1860 he returned home on sick leave, and in 1867 was promoted Major. Afterwards he joined the Argyllshire Highlanders, which regiment he commanded from 1869 to 1876. In 1882 he was promoted Major-General, and in 1884 he succeeded to the family estates. In 1887 he retired from the Army with the rank of Lieutenant-General. He did work in India on roads and railways in connection with the Public Works Department.

Since his succession to his estate at Riddell, Roxburghshire, General Sprot devoted himself to the pursuits of a country gentleman, and always took the keenest interest in public affairs. He was a Deputy-Lieutenant and Justice of the Peace for the county.

In 1893 he started the interesting series of rainfall and meteorological observations which he kept up to the end. One of General Sprot's most interesting meteorological experiments was made with electric-recording anemometers fixed at various heights on a great steel flagstaff 130 ft. high, which he had erected in his grounds at Lilliesleaf.

He died on March 19, 1907, aged 77 years.

He was elected a Fellow of this Society on December 20, 1899.

Lawrence Charles Hills Young was the second son of the Rev. H. Savill Young, for some years rector of Slough. He was educated at Marlborough, and then proceeded to Exeter College, Oxford, where he took honours in Indian History. He went out to India in October 1901, and joined the staff of a large mercantile firm in Bombay. He returned to England on account of ill health in the summer of 1907, and died at Henley-on-Thames on September 8, at the age of 30.

His recreation as a boy was insect collecting and entomology, and he was a keen observer of Nature. When in Bombay he rendered valuable assistance to the Natural History Society by taking in hand the rearrangement and classification of the entomological collections.

He was elected a Fellow of this Society on May 16, 1906.

APPENDIX IV.

PURCHASES DURING THE YEAR 1907.

1. Books.

International Catalogue of Scientific Literature. Fifth Annual Issue, C. Physics. F. Meteorology.

Newman, G.—Infant Mortality. A Social Problem. 8vo. London, 1906.

SCHARF, E.—Der Hagel. 8vo. Halle-a.-S., 1906.
WALDO, F.—Elementary Meteorology for High Schools and Colleges. New York, 1896.
WASHINGTON, ENGINEER DEPARTMENT, U.S. ARMY.—Report upon United States Geographical Surveys west of the One Hundredth Meridian, Vol. 2.—Astronomy and Barometric Hypsometry. 4to. Washington, 1877.

2. PHOTOGRAPHS.

Photos of large Hailstones at Charlestown, Natal (4).

APPENDIX V.

DONATIONS RECEIVED DURING THE YEAR 1907.

1. BOOKS AND PAMPHLETS.

Presented by Societies, Institutions, etc.

AACHEN, METEOROLOGISCHES OBSERVATORIUM.—Deutsches meteorologisches Jahrbuch, Aachen, 1905.—Die wolkenbruchartigen Regenfälle im Rur- und Erstgebiete am 7., 10., 17. Juni und 5. Juli 1905.

BANGALORE, CENTRAL OBSERVATORY.—Meteorology in Mysore, 1906.—Report on the Rainfall Registration in Mysore, 1906.

BARBADOS, COLONIAL SECRETARY'S OFFICE.—Returns of Rainfall in Barbados, 1907.

BARCELONA, OBSERVATORIO BELLOCH.—Hojas Meteorológicas, 1904.

BATAVIA, MAGNETICAL AND METEOROLOGICAL OBSERVATORY.—Observations, 1905, Appendices 1-3.—Rainfall in the East Indian Archipelago, 1905.

BELGRADE, OBSERVATOIRE CENTRAL.—Bulletin Mensuel, 1 and 2.

BERLIN, DEUTSCHE METEOROLOGISCHE GESELLSCHAFT.—Meteorologische Zeitschrift, Dec. 1906 to Nov. 1907.

BERLIN, GESELLSCHAFT FÜR ERDKUNDE.—Zeitschrift, 1906, No. 10, to 1907, No. 9.

BERLIN, KÖNIGLICH-PREUSSISCHES METEOROLOGISCHES INSTITUT.—Bericht über die Tätigkeit, 1906.—Deutsches meteorologisches Jahrbuch, 1905-6, Preussen und benachbarte Staaten.—Ergebnisse der Beobachtungen an den Stationen II. und III. Ordnung, 1901.—Ergebnisse der Gewitter-Beobachtungen, 1901-2.—Ergebnisse der magnetischen Beobachtungen in Potsdam, 1902.—Ergebnisse der meteorologischen Beobachtungen in Potsdam, 1903.—Ergebnisse der Niederschlags-Beobachtungen, 1903-4.—Internationaler meteorologischer Kodex. Im Auftrage des Internationalen meteorologischen Komitees, bearbeitet von G. Hellmann und H. H. Hildebrandsson.

BIRMINGHAM AND MIDLAND INSTITUTE.—Records of Meteorological Observations taken at the Observatory, Edgbaston, 1906.

BREMEN, METEOROLOGISCHE STATION.—Deutsches meteorologisches Jahrbuch, 1906.

BRISBANE, GENERAL REGISTER OFFICE.—Vital statistics, 1905.

BRISBANE, ROYAL GEOGRAPHICAL SOCIETY OF AUSTRALIA, QUEENSLAND.—Queensland Geographical Journal, 22.

BRITISH NEW GUINEA, COLONIAL SECRETARY'S OFFICE.—Annual Report for the year ending June 30, 1906.

BRUSSELS, ACADÉMIE ROYALE DE BELGIQUE.—Annuaire, 1907.—Bulletin de la classe des sciences, 1906, No. 10, to 1907, No. 8.

BRUSSELS, CONGRÈS INTERNATIONAL POUR L'ÉTUDE DES RÉGIONS POLAIRES.—Rapport d'ensemble. Documents préliminaires et compte rendu des séances, Sept. 7-11, 1906.

BRUSSELS, OBSERVATOIRE ROYAL.—Annales, Nouvelle Série, Astronomique, 9.—Physique du globe, 3.—Annuaire astronomique, 1907.—Annuaire météorologique, 1907.—Les observatoires astronomiques et les astronomes.

BRUSSELS, SERVICE MÉTÉOROLOGIQUE DE BELGIQUE.—La foudre et les arbres. Étude sur les foudroiements d'arbres constatés en Belgique pendant les années 1884-1906. Par E. Vanderlinden.

BUCHAREST, INSTITUT MÉTÉOROLOGIQUE DE ROUMANIE.—Analele, 1902.—Buletinul Lunar al Observatiunilor Meteorologice din România, 1905.—Climatologia Bucuresteana, 1902-3.—Materiale pentru Climatologia României, 1905.—Meteorologia si Metrologia în România dr S. C. Hepites.—Starea udometrică si agricolă a României, Nos. 27-43.

BUDAPEST, K. UNG. REICHSANSTALT FÜR METEOROLOGIE UND ERDMAGNETISMUS.—Jahrbuch 1904, Teil 4; 1905, Teile 1 and 3.

BUITENZORG, INSTITUT BOTANIQUE DE L'ÉTAT.—Observations météorologiques, 1905-6.

CAIRO, SOCIÉTÉ KHÉDIVIALE DE GÉOGRAPHIE.—Bulletin, 6, Nos. 10 to 12.

CAIRO, SURVEY DEPARTMENT, PUBLIC WORKS DEPARTMENT.—Meteorological Report, 1904, part 1.—The Climate of Abbassia near Cairo, by B. E. F. Keeling.—The Rains of the Nile Basin in 1906, by Capt. H. G. Lyons.

CALCUTTA, METEOROLOGICAL OFFICE.—Indian Daily Weather Charts, Dec. 1, 1906, to Nov. 30, 1907.—Indian Monthly Weather Review, May to Dec. 1906.—Indian Meteorological Memoirs, 18, parts 1 and 3.—Memorandum on the Meteorological conditions prevailing in the Indian Monsoon Region before the advance of the South-west Monsoon of 1907, with an estimate of the probable Distribution of the Monsoon Rainfall, 1907.—Memorandum on the Meteorological conditions prevailing in the Indian Monsoon Region during the first half of the South-west Monsoon Period of 1907 with anticipations regarding the Monsoon Rainfall during Aug. and Sept. 1907.—Rainfall of India, 1905.—Report on the Administration, 1906-7.

CAPE TOWN, SOUTH AFRICAN PHILOSOPHICAL SOCIETY.—Transactions, 16, parts 4-5; 17, parts 1-3; 18, part 1.

CARLSRUHE, CENTRALBUREAU FÜR METEOROLOGIE UND HYDROGRAPHIE IM GROSSHERZOGTUM BADEN.—Jahrbuch, 1906.—Niederschlags-Beobachtungen der meteorologischen Stationen im Grossherzogtum Baden, 1906, part 2; 1907, part 1.

CHICAGO, GEOGRAPHIC SOCIETY.—Lantern Slide Illustrations for teaching of Meteorology.

CHRISTIANIA, NORWEGISCHES METEOROLOGISCHES INSTITUT.—Jahrbuch, 1906.—Nedböriagttagelser i Norge, 1906.

CHRIST'S HOSPITAL, NATURAL HISTORY SOCIETY.—Annual Report, 1906.

COLORADO, COLLEGE OBSERVATORY.—Annual Meteorological Summary, 1906.

COPENHAGEN, DANSK METEOROLOGISK INSTITUT.—Bulletin météorologique du Nord, Nov. 1906 to Oct. 1907.—Nautisk-Meteorologisk Aarbog, 1906.—Meteorologisk Aarbog, 1903, part 2; 1904, parts 1 and 2; 1905, part 1; 1906, part 1.—Annales de l'observatoire magnétique de Copenhague.

CORDOBA, OFICINA METEOROLÓGICA ARGENTINA.—Carta del Tiempo, Nov. 1906 to Oct. 1907.

CORNWALL COUNTY COUNCIL, SANITARY COMMITTEE.—Monthly Report, Dec. 1906 to Nov. 1907.

CRACOW, K. K. STERNWARTE.—Meteorologische Beobachtungen, Dec. 1906 to Sept. 1907.

CROYDON, NATURAL HISTORY AND SCIENTIFIC SOCIETY.—Daily Rainfall in the Croydon District, Dec. 1906 to Oct. 1907.—Report of the Meteorological Sub-Committee, 1906.

DAVOS PLATZ, KURVEREIN.—Davoser Wetterkarte, Nov. 1906 to Oct. 1907.

DUBLIN, ROYAL DUBLIN SOCIETY.—Economic Proceedings, 1, parts 9 to 11.—Scientific Proceedings, 11, parts 13 to 20.—Transactions, 11, Nos. 4 to 6.

DUBLIN, ROYAL IRISH ACADEMY.—Proceedings, 26 A., part 2; 27 A., parts 1 and 2.

EALING, SCIENTIFIC AND MICROSCOPICAL SOCIETY.—Report and Transactions, 1906-7.

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WETHERALL, G. B.—Weather in 1906 (at Worcester).

WETHERILL, H. E.—Hygromedry.

WILLCOCKS, Sir W.—The Irrigation of Mesopotamia.

WOOD, (Dr.) G. B.—A few Medical Notes on Sandown, Isle of Wight, as a Health Resort in Winter.

WORTH, R. H.—Twenty-fourth Report (Third Series) of the Committee on the Climate of Devon.

WRAY, C.—Federated Malay States. Pahang Administration Report, 1906.

YAMASHINA, PRINCE.—Ergebnisse der meteorologischen Beobachtungen auf dem Tsukubasan, 1902.

2. PHOTOGRAPHS.

GREENWOOD, H. B.—Floods at Kendal, Nov. 2, 1898 (4).

3. LANTERN SLIDES.

LANDER, A.—Lander and Smith's Recording Instruments (11).

Large Hailstones.

A correspondent to a South African newspaper writes:—

"On the afternoon of December 1, 1907, we were visited by a terrible hail-storm in the district of Jacobsdal, the part most affected being Lower Riet river. Hail fell continuously for about 25 minutes, and some pieces weighed as much as 3½ oz., and were as large as ducks' eggs. The live-stock did not suffer very much, but the plantations are largely destroyed. On one of the farms a piece of lucerne in its prime was beaten down so that it almost resembled a field that had just been mown. Elderly people say that they have never seen the like in this district."

Hail Shooting in Italy.

Mons. A. Angot, the Director of the Bureau Central Météorologique, Paris, calls attention to a slight error on pages 25 and 26 in the last number of the *Quarterly Journal* in the Note on Hail Shooting in Italy. He says:—

"The Casa Aulagne di Monteux is not a station, but a manufacturing firm, the house of Aulagne of Monteux, which sells the fusees (rockets?) for shooting against hail, and thinks that these fusees attain the height of 1200 yards; which seems to me extremely doubtful.

"In Italy they tried, after the Greinitz cannons, the Aulagne fusees, and then Marazzi bombs."

PROCEEDINGS AT THE MEETINGS OF THE SOCIETY.

January 15, 1908.

Ordinary Meeting.

Dr. HUGH ROBERT MILL, President, in the Chair.

CHARLES JOHN BARKER, Hillcroft, Russell Hill, Purley;
ELIOTT SCARLETT CURREY, M.Inst.C.E., Fachlwyd Hall, Ruthin;
Rev. RICHARD PATESHALL DANSEY, Kentchurch Rectory, Hereford;
CHARLES EDWARD JEFFERIES ESDAILE, J.P., Cothelestone House, Taunton;
MURRAY T. FOSTER, Cullompton, Devon;
ERNEST GOLD, M.A., 3 Devana Terrace, Cambridge;
Rev. GEORGE RANDOLPH HADOW, Wylye Rectory, Wilts;
JOHN ROBERT GETHIN JONES, Taly Cafn, N. Wales;
JOHN JONATHAN KERMODE, 62 Dale Street, Liverpool; and
MISS CORDELIA F. MARSHALL, Skelwith Fold, Ambleside,
were balloted for and elected Fellows of the Society.

January 15, 1908.

Annual General Meeting.

Dr. HUGH ROBERT MILL, President, in the Chair.

Mr. E. H. S. BRUCE and Mr. H. N. FFARINGTON were appointed Scrutineers of the ballot for the Council.

REPORT OF THE COUNCIL.

THE PRESIDENT remarked that as everyone had received a copy of the Report of Council, he proposed that this should be taken as read. He therefore moved that "The Report be received and adopted, and that it be printed in the *Quarterly Journal*." The Report seemed to him to be very satisfactory. The pulse of the Society was generally taken to be the number of Fellows, especially of new Fellows, as compared with the number of previous years. This year the number of Fellows was larger than ever before, and those removed from the Society for various reasons were not so numerous as usual. The Report set forth the work done during the year. He, the President, would specially refer to the work done by the Kite Committee, which concerned itself with the exploration of the upper air, and the share which the Society had taken in forwarding the national and international investigation of the atmosphere at points far above the surface. This investigation had been carried on in different parts of the British Isles, and the results had occupied a good deal of the attention of the Society at its recent Meetings.

Another Committee showing excellent work was the Local Scientific Societies' Committee, which had the object of fostering the interest of the public in meteorology and improving the position of meteorological science in this country. An interesting feature was the offer of three prizes to teachers in a competition organised by the Society, for the best school lesson on climate or weather, which had the effect of directing a quite remarkable amount of public attention to the subject. The least satisfactory item of the Report was, perhaps, the stationary state of the Research Fund. There was no increase in this Fund,

and no draft had been made upon it; possibly it would increase more rapidly if it were more used, but its object was being carried out to a certain extent by means of other funds.

The President then referred to the very successful Dinner which had taken place last year, and was, he hoped, the first of a long series. He went on to say that the Library was unique and rapidly growing. It contained a remarkable collection of books leading back to the earliest times, while the Bibliography of Meteorology was the most extensive in the world. The Balance-sheet was favourable, showing a comfortable sum in hand. There was, he regretted to say, a long list of deaths of Fellows, and especially of Honorary Members.

Mr. F. CAMPBELL BAYARD, in seconding the Resolution, remarked that the Prize Competition organised by the Local Scientific Societies' Committee was likely to prove a great success. Already 1500 circulars respecting it had been sent out, and the Competition was attracting an immense amount of interest. He, Mr. Bayard, thought that special mention should be made of the death of Admiral Maclear, an old and valued Fellow of the Society.

The Resolution was adopted. [The Report is printed on p. 113.]

THANKS TO THE COUNCIL AND AUDITORS.

Mr. A. BREWIN moved: "That the thanks of the Society be given to the Council for their services during the past year, and also to the Auditors." He said that he did not think any Society in London had a more hard-working Council. It was thanks to them that the Society was in the prosperous condition which the Report revealed.

Capt. A. CARPENTER, in seconding the Resolution, remarked on the great increase in the number of Fellows, for which we were chiefly indebted to our popular President. We took as a matter of course the work done by the Council as shown in the Annual Report, and expected so much from them, that in view of the advances made in the navigation of the atmosphere we should now expect them to sail about over London and decide Meteorological problems on the spot.

The Resolution was adopted.

INSTITUTION OF CIVIL ENGINEERS.

Mr. F. DRUCE proposed "That the thanks of the Royal Meteorological Society be communicated to the President and Council of the Institution of Civil Engineers for having granted the Society free permission to hold its Meetings in the rooms of the Institution." He remarked on the great convenience it was to have such a room at their disposal, especially with the present large number of Fellows.

Mr. J. E. CLARK said that it was a pleasure to second a motion of that kind, and they must all appreciate the goodness of the Institution of Civil Engineers in entertaining them for so many years. He had been wondering how long the Society had enjoyed the Institution's hospitality, and had found that it dated back to the time when Robert Stephenson was the President of the Royal Meteorological Society, and obtained for them this very generous assistance for meteorology. With the present large number of Fellows, and so rapid an increase, the importance of having such a room became more and more obvious.

THE PRESIDENT, in putting the motion to the Meeting, remarked that he always felt that, thanks to the kindness of the Institution, they had the finest meeting room in London.

The Resolution was adopted.

Presentation of the Symons Memorial Gold Medal.

The President said that he now approached what was the pleasantest part of his duties, because it was to render a tribute at the same time to one of the most distinguished of modern meteorologists, and to the memory of his great predecessor in that chair, and in other work, Mr. G. J. Symons. They were aware that the Gold Medal was established in memory of Mr. Symons, and was awarded every alternate year by the Society to a meteorologist for the work he had done in advancing the science. On the first occasion the Medal was awarded to the late Dr. Alexander Buchan; on the second, to the famous Austrian meteorologist, Dr. J. Hann; on the third, to Sir Richard Strachey; and on this the fourth occasion, the name of the recipient and the nature of his work would appear in an extract from the Council Minutes which the Secretary would now read.

The Secretary, Mr. H. Mellish, then read the following extract from the Minutes of the Council Meeting, dated October 16, 1907:—

"It was resolved that the Symons Memorial Gold Medal for 1908 be awarded to Monsieur Léon Teisserenc de Bort for distinguished work done in connection with meteorological science.

"Léon Teisserenc de Bort commenced his scientific work in 1878 as a member of the staff of the Bureau Central Météorologique de France. From 1880 to 1892 he was chief of the department of General Meteorology. He resigned his appointment in 1892 in order to devote himself to experimental research in meteorology. In 1896 he founded an Observatory for the study of Dynamical Meteorology at Trappes, which has become famous for the boldness of its enterprise and the success of its methods in the study of the upper air.

"M. Teisserenc de Bort has also organised and directed for special purposes in connection with that study, schemes for exploration of the upper air in Denmark and Lapland, on the Cattegat, and the Zuyder Zee. He has transformed a Hull fish-carrier into a floating meteorological observatory, which under the name of the yacht *Otaria* has carried out—partly with the assistance of Professor Rotch—extensive researches in the Mediterranean and over the inter-tropical belt of the Atlantic Ocean.

"His earlier published papers include a magnetic survey of parts of Algeria, Tunis, and the Sahara, undertaken during his periods of leave while still attached to the Bureau Central. And while head of the department, he contributed sixteen papers on the general circulation of the atmosphere; the distribution of the meteorological elements over the globe, and their mutual relations; and the distribution of barometric pressure at different levels. In this connection it is sufficient to mention the introduction of the idea of "centres of action of the atmosphere"; the relation of the anomalies of temperature and pressure; the charts of isobars for 4000 metres level, showing general cyclonic circulation round each pole above the irregularities of the surface; and the analysis of vertical motion in cyclones and anticyclones,—as important general results that constitute definite advances in our knowledge of the meteorology of the globe.

"But M. Teisserenc de Bort is best known for his work upon the upper air by means of ballons-sondes and kites. The equipment used was designed and constructed at Trappes, and the results obtained have added largely to our knowledge of the upper air. The establishment of the existence of the so-called isothermal layer at a height of about ten kilometres is largely due to the work of the Observatory. The identification of the return anti-trade above the North-east tradé-wind; the structure of the intervening layer;

and the comparison of the temperatures in the highest layers in various latitudes, which apparently show a gradient of temperature from the pole to the equator, instead of one, as might be expected, in the opposite direction, —are scientific achievements of M. Teisserenc de Bort, in collaboration, as regards some parts of the work, with colleagues of various countries.

"With Professor Hildebrandsson, M. Teisserenc de Bort has recently completed a historical treatise upon Dynamical Meteorology. The advances made in that subject by his personal exertions and at his own charges must always remain for future historians among the most original achievements of the present generation."

THE PRESIDENT, addressing M. Teisserenc de Bort, said :—

"M. Teisserenc de Bort, I feel that there is a special appropriateness in giving this Medal to you. If Mr Symons' life teaches us anything—and it teaches much—it is that the enthusiastic perseverance of an individual with a definite aim in view can often accomplish work which would be difficult for any public department to carry out officially. Like Mr. Symons, you entered the meteorological service of your country, and like him, you left it in order to pursue a definite line of research in a particular direction which had previously been neglected. Your conspicuous success claims in this country, more perhaps than in other countries, a special meed of praise, because here we are in the habit of seeing great results accrue from individual effort in scientific and public life ; and when we see the same spirit animating the people of other countries and leading to such results as you have achieved, our hearts glow with the warmest appreciation. And it is extremely gratifying that we have within our reach the means of expressing this feeling. It is indeed fitting that the Medal awarded largely for work done by free balloons should go to a countryman of the great pioneer Montgolfier. We feel a special satisfaction, also, that this Medal goes to a citizen of the country which is our nearest neighbour on the Continent, and, amongst all the friendly nations of the world, one which we hold the friendliest. It is to me, as a Scotsman, an additional gratification to claim that nation as an ancient ally of my country, and the fact that the feeling, historical in the north, is now shared by the whole United Kingdom, is surely one of the best tributes to that subordination of national boundaries to international unity which finds its best expression in the brotherhood of men of science throughout the world. I hand you the Symons Memorial Gold Medal with our heartiest good wishes."

M. TEISSERENC DE BORT said : "Ladies and gentlemen, I am very sorry that I am not able to speak English fluently in order to express to the President and the Fellows of the Royal Meteorological Society my best thanks for the great honour done me by the award of the Symons Gold Medal. I therefore ask you to allow me to speak in French.

"Je suis particulièrement sensible à cette distinction, d'autant plus que des liens de longue amitié me rattachaient à G. J. Symons dont je fis la connaissance personnelle au Congrès météorologique de 1878. J'avais annuellement le plaisir de me retrouver avec lui et nous étions en correspondance assez régulière.

"Au moment de l'Exposition de 1889, où il séjourna assez longtemps à Paris, il se préoccupait d'un problème qui fixe depuis quelques années, d'une manière particulière, l'attention des météorologistes et qui consiste à déterminer la liaison entre les divers phénomènes qui accompagnent les orages et les grains, tonnerre, pluie, vent, grèle, etc.

"L'appareil qu'il inventa à ce sujet, le brontomètre, permet à l'observateur de déterminer exactement le temps auquel commence ou finit un phénomène donné.

"La commission d'étude du Krakatoa, présidée par Symons, fit faire un grand

LÉON TEISSERENC DE BORT.

(*Symons Medallist*, 1908).

SAMPLE COPY

pas à la connaissance de la circulation générale de l'atmosphère en démontrant l'existence d'un courant E.O. au-dessus des régions équatoriales jusqu'à une très grande hauteur et mesurant sa vitesse par le déplacement des cendres du volcan.

"Ainsi Symons qui avait déjà créé en Angleterre cet admirable service de la mesure de la pluie, d'une si grande utilité,—et avait su le faire vivre par des ressources privées,—donna aussi une notable partie de son temps à l'étude de l'atmosphère dans ses mouvements généraux.

"Au moment où l'étude de l'atmosphère libre prend une si grande extension, comme nous le rappelait si bien Mr. le Président dans son discours, nous devons regretter encore plus que G. J. Symons ne soit plus au milieu de nous pour participer à ces recherches si captivantes.

"Permettez-moi de vous exprimer de nouveau tous mes remerciements pour la belle médaille qui vient de m'être donnée et qui porte en effigie un excellent portrait de G. J. Symons. C'est une distinction dont je sens tout le prix ; en même temps cet objet précieuse évoquera en moi le souvenir d'une précieuse amitié."

[A portrait of Monsieur Léon Teisserenc de Bort is given on Plate II.]

President's Address.

The President then delivered an Address on "Map-Studies of Rainfall" (p. 65).

Dr. W. N. Shaw, in proposing that "the thanks of the Society be given to Dr. Mill for his services as President and for his Address, and that he be requested to allow it to be printed in the *Quarterly Journal*," remarked that Dr. Mill had anticipated the latter part of the resolution by intimating that he would give permission for the Address to be printed in the *Quarterly Journal*. As regards the former part, he, Dr. Shaw, trusted that Dr. Mill would allow him to include the Address among the services of the President, for he thought the Address could be regarded as one of the greatest of these services. Dr. Mill was much to be congratulated on his year of office: there was, first, the remarkable increase in the number of Fellows; secondly, the development of the investigation of the upper air, appropriately represented by M. Teisserenc de Bort's presence that evening; and, thirdly, the remarkably interesting Address they had just heard.

He would like to touch on two points in the Address. Dr. Mill proposed to regard the shower as a unit for the study of rainfall, thereby associating himself with workers in other branches of the subject. The closer investigation of the shower promised to be a starting-point of very important work in dynamical meteorology as well as in rainfall. Then he wished to emphasise the enormous advantage of coloured maps, which had been proved so conspicuously during the Address. Perhaps Dr. Mill would tell them how to get reproductions of maps printed in colour, in such a way as to form illustrations in the *Journal* as effective and satisfactory as the maps shown on the wall.

Mr. W. H. Dines seconded the Resolution.

The Resolution was adopted.

The President, in reply, said that with regard to the coloured maps no difficulty need arise except with the Exchequer. He thanked them very much for their reception of his Address, for the silent attention with which they had listened to it, and for the generous applause with which the Resolution had been carried.

ELECTION OF COUNCIL.

THE SCRUTINEERS then declared the following to be the Council for the ensuing year :—

PRESIDENT.

HUGH ROBERT MILL, D.Sc., LL.D., F.R.S.E., F.R.G.S.

VICE-PRESIDENTS.

RICHARD BENTLEY, F.L.S., F.R.G.S.
WILLIAM HENRY DINES, B.A., F.R.S.
EDWARD MAWLEY, F.R.H.S.
WILLIAM NAPIER SHAW, M.A., D.Sc., F.R.S.

TREASURER.

CHARLES THEODORE WILLIAMS, M.A., M.D., F.R.C.P., M.V.O.

SECRETARIES.

FRANCIS CAMPBELL BAYARD, LL.M.
HENRY MELLISH, D.L., J.P., F.R.G.S.

FOREIGN SECRETARY.

ROBERT HENRY SCOTT, M.A., D.Sc., F.R.S.

COUNCILLORS.

WALTER WILLIAM BRYANT, B.A., F.R.A.S.
Capt. WARREN FREDERICK CABORNE, C.B., F.R.G.S., F.R.A.S.
Capt. MAURICE HARVEY CLARKE, F.R.A.S., F.R.G.S.
RICHARD HENRY CURTIS.
HENRY NEWTON DICKSON, M.A., D.Sc., F.R.S.E., F.R.G.S.
FRANCIS DRUCE, M.A., F.R.G.S.
WILLIAM ELLIS, F.R.S., F.R.A.S.
Capt. MELVILLE WILLIS CAMPBELL HEPWORTH, C.B., F.R.A.S.
RICHARD INWARDS, F.R.A.S.
BALDWIN LATHAM, M.Inst.C.E., F.G.S.
RUDOLF GUSTAV KARL LEMPFERT, M.A.
Capt. DAVID WILSON-BARKER, F.R.S.E., F.R.G.S.

February 19, 1908.

Ordinary Meeting.

Dr. HUGH ROBERT MILL, President, in the Chair.

Md. MUFAZZAL HOOSEIN, Camp Sibsagarh, Assam ;
PERCY RICHARD JAMESON, 98 Clerkenwell Road, E.C. ;
GEORGE ROBERT JEBB, M.Inst.C.E., Great Barr, Birmingham ;
Capt. JAMES ROBERT RAE, 73 Caledonia Road, Saltcoats, N.B. ;
SRIRAM VENKATA SUBBA SETTI, B.A., Chikmagahur, Mysore ;
Capt. HENRY STRONG, Union-Castle Co., Fenchurch Street, E.C. ;
OCTAVIUS THOMAS, Pentre, Rhondda, Glam. ;
JOHN WRENCH TOWSE, Sunnydene, Bickley ;
FRANK WOOLNOUGH, Museum, Ipswich ; and
JOHN HOWIE WYLIE, Heath House, Woking,

were balloted for and elected Fellows of the Society.

THE PRESIDENT said that before proceeding to the ordinary business, it was his melancholy duty to record the deaths of several distinguished members of the Society. These losses had been particularly numerous lately among the Honorary Members. They had now to deplore the death of Monsieur A. Lancaster, the head of the Meteorological Service of Belgium, and there were four vacancies in the list of Honorary Members. General Sir Richard Strachey, who had received the Symons Memorial Gold Medal in 1906, had ended his long and brilliant career. Both the British holders of this Medal were now no more. The varied contributions to Meteorological Science by Sir Richard Strachey had been brought so fully before the Society in 1906, that it was unnecessary to dilate upon them now; but he must give expression to their deep regret at the passing of so magnificent a veteran.

He wished to refer to several points in the activity of the Society. One was that no less than 180 Essays had been received in response to the Society's request to teachers to submit specimen lessons on Meteorology. The extremely laborious task of going through these had been commenced, and it was hoped that the result might soon be announced. There was to be a meeting of meteorologists of the British Empire in May at Ottawa, which would be the first attempt made to unite the meteorologists of the Empire in conference. An invitation had been received from the Royal Society of Canada to send a delegate. The time of year selected made it difficult for many meteorologists to get away from their more immediate duties, but the Society hoped that Dr. Shaw would act as its representative to convey their good wishes.

The President concluded by remarking that the next Meeting of the Society would take place on the 11th instead of the 18th of March, when their distinguished Honorary Member, Professor Hellman, would give them a lecture on the "Dawn of Meteorology." Most of them were aware that Dr. Hellmann had last visited them on the occasion of their Jubilee; he was a fluent English speaker, and he—the President—trusted all the Fellows would unite in making the meeting one of the largest and most successful ever held by the Society.

The following communications were read:—

1. "FORMATION OF SNOW-ROLLERS." By CHARLES BROWETT (p. 87).

2. "COMPARISON OF SHIPS' BAROMETER READINGS WITH THOSE DEDUCED FROM LAND OBSERVATIONS." By ERNEST GOLD, M.A., F.R.Met.Soc. (p. 97).

CORRESPONDENCE AND NOTES.

Lectures on Meteorology.

Mr. W. MARRIOTT has recently given lectures on meteorological subjects, in connection with the Society's scheme for diffusing a knowledge of Meteorology, at the following places: January 29, Charterhouse, Godalming; March 6, Reading School, Reading.

Prize Competition for Teachers.

The Council of the Royal Meteorological Society have considered the Reports of the Examiners on the Essays on "Climate or Weather," which were sent in by elementary teachers for the prize competition mentioned on p. 55 of the last No. of the *Quarterly Journal*, and have made the following awards:—

1st Prize, £5, W. C. Upshall, Broughton, Stockbridge.

2nd Prize, £3, Miss A. B. Phillips, 34 Blythe Hill, Catford.

3rd Prize, £2, Albert V. Stevenson, St. Paul's School, Sunderland.

Extra Prizes, £1 each—John Young, Barrock School, by Wick; Henry Collar, Lavender Hill School, Clapham Junction.

In addition to the above, the following prizes have been awarded for Essays sent in by Pupil Teachers:—

1st Prize, £1, Arnold B. Tinn, 28 Macaulay Road, Birkby, Huddersfield.

2nd Prize, 10s., Miss Daisy E. James, Church House, Wokingham.

Meteorological Work at the Radcliffe Observatory, Oxford, 1907.

The usual meteorological observations and automatic registrations have been maintained, and the results forwarded regularly as heretofore to the Meteorological Office (by daily telegram), the Registrar-General, the Thames Conservancy, the Metropolitan Water Board, local newspapers, to public and sanitary authorities, and numerous private inquirers.

During the year 1907 the five underground platinum thermometers were read daily. Observations made with these thermometers have been carried on without interruption since November 1, 1898, but it is intended to discontinue their regular use at the end of 1909. At the request of the Director of the Meteorological Office, daily comparisons have been made between the platinum thermometers and two ordinary mercurial thermometers of Symons's underground pattern at depths of 6 ins. and 3 ft. 6 ins.

All the automatic instruments have worked well during the year.

The following are the chief characteristics of the weather noted at Oxford during the year 1907:—

The mean reading of the barometer (reduced to 32° F.) was 29·737 ins., which is 0·010 in. higher than the mean for the preceding 52 years. The highest reading, 30·626 ins., occurred on January 23; the lowest was 28·571 ins. on December 13.

The mean temperature of the air for the year was 48°·7, or 0°·2 below the mean for the preceding 79 years. The maximum temperature was reached on May 12, viz. 78°·5, and the minimum 20°·2 on January 25. The lowest reading of the thermometer exposed on the grass was 12°·7 on February 3.

The differences of the mean monthly temperatures from the corresponding means for the preceding 79 years are

Jan.	+0°·2	May	−0°·3	Sept.	+1°·1
Feb.	−1·9	June	−3·5	Oct.	+1·1
Mar.	+2·6	July	−3·8	Nov.	+1·5
April	−0·4	Aug.	−1·2	Dec.	+2·0

Bright sunshine was recorded during 1432 hours, or 32 hours less than the mean for the preceding 26 years. The monthly differences from the mean are indicated in the following table:—

	hrs.		hrs.		hrs.
Jan.	+25	May	−57	Sept.	+21
Feb.	+25	June	−61	Oct.	+ 1
Mar.	+74	July	−36	Nov.	+ 2
April	−17	Aug.	− 9	Dec.	− 1

Rainfall on the ground amounted to 27·024 ins., a total which is 0·997 in. above the average for the preceding 92 years.

The number of "rainy days" (*i.e.* 0·010 in. and over) was 155.

The divergences of the monthly totals from the corresponding mean values for the previous 92 years were

	ins.		ins.		ins.
Jan.	−1·349	May	+0·363	Sept.	−1·874
Feb.	−0·504	June	+0·637	Oct.	+2·493
Mar.	−0·739	July	+0·833	Nov.	−0·099
April	+0·506	Aug.	−1·100	Dec.	+1·830

A fine display of aurora borealis was observed on February 9.

On January 21, 1907, Mr. E. E. M'Clellan, who had held the post of third assistant since 1892, died rather suddenly. His connection with meteorology was a long one. Previously to his appointment at Oxford he had served for 12 years in the magnetical and meteorological department of the Royal Observatory, Greenwich. He was an accurate observer and a good computer, possessing also considerable skill in photography.—ARTHUR A. RAMBAUT, Radcliffe Observer, March 2, 1908.

Tropical and Sub-Tropical Cyclones in North-West of Madagascar.

For some years past the number of cyclones north-west of Madagascar has considerably increased.

So far as I am aware, no tropical cyclones have ever been recorded in the Cosmoledo and Aldabra groups. The only record of a cyclone northward of this latitude and at an earlier date is that which visited the Seychelles groups 45 years ago (October 1862).

Mr. James Spurs, formerly lessee of these islands, once told me that a cyclone visited these islands some 20 years ago; but no sufficient information could be obtained from him to prove that it was a cyclone, as he himself was absent from the island at the time. There were only some fishermen on the island, and not one amongst them could note phenomena during a storm. But according to the scanty information which Mr. Spurs related to me, and which he had gathered from his fishermen, I quite agree with our old island meteorologist that this was a cyclone that curved south-eastward of Aldabra island early in the month of October.

To my knowledge the most northern limit where cyclones, northward of Madagascar, curved was over the islands of Farquhar and Glorieuse, and they very often caused great damages to property.

The cyclone which visited Astore, Cosmoledo, and Aldabra islands on November 2 and 3, 1907, was an unprecedented one for these islands, with regard to time of the year, the direction and force of the wind, and the suddenness, rapidity, and extent of changes which took place.

According to the information gathered from the manager of these islands, it appeared that the weather had been threatening since the preceding day with sinister aspect. Towards the afternoon on November 2 the wind blew in sudden gusts from southward, with high, tempestuous sea, and there were loud thunder and vivid lightning at times. At midnight the wind increased violently, and veered from South to South-west. Thunder continued at frequent intervals in the south, south-west, overhead, and north-west, with blinding lightning; and the roaring of the waves over the surf was something frightful. Towards the morning, on November 3, the wind veered to West and North-west, where it remained steady and blew a hurricane of much violence.

During that time Astore and Cosmoledo islands were devastated by that tempestuous foul weather.

Heavy rainfall, accompanied by wind and sea, flooded the cocoa-nut plantations in the lagoon at Astore, the opening of the lagoon being in the south-western part of the island; and so, when the wind veered to the South-west and West, enormous quantities of water were sent into the lagoon. Signs of the flood can still be seen at a distance of 100 yards from the beach, in the lagoon, right in the plantations.

Most of the bigger cocoa-nut trees on Astore and Cosmoledo islands were blown down by this terrible hurricane. The inhabitants suffered much during this dreadful time.

All the houses were blown down; the manager's house at Cosmoledo was shifted to a distance of about 18 feet from west to east, the roof of the house

was carried away to a distance of about a quarter of a mile by the strength of the Westerly wind. Some of the labourers' huts have never been seen again. Numbers of corrugated iron sheets were seen flying in the air like birds, cutting down small trees here and there like sharp axes, and have never been picked up again, having been blown right out into the sea.

At Aldabra the same weather was experienced, but not so foul, the wind blowing in the same direction and force as at Astore and Cosmoledo, but no rain, thunder, or lightning was observed; only the weather was dark and gloomy, all indicative of an advancing storm. There was a barometer on the island, and Mr. Sauzier, the manager, told me that it fell to a little over 29·50 ins., when the wind was blowing at its strongest from West to North-west, and steady. Towards the afternoon, on November 3, the conditions were more promising, wind and sea abating, and there was appearance of better weather.

Correct observations could not be obtained, as there were no instruments available on the island for the purpose of recording meteorological observations.

According to the information received this was a cyclone, with all the characteristics of a small diameter, and the centre must have passed southward of Astore and Cosmoledo islands.—Capt. R. PARCOU, Victoria, Seychelles.

Scintillation and Rippling of Distant Lights.—I was at Brighton from March 12 to 20, 1908, and made the following observations on the scintillation of the lights at Worthing as seen from Brighton for comparison with those by Mr. Marriott in the *Quarterly Journal*, **24**, p. 50.

Time.	Wind.	Force.	Weather.	Worthing Lights.
March 12, 8 p.m.	NE.	1	Fine, moonlight	Lights steady.
,, ,, 10 ,,	Calm	0	Sea fog	Lights invisible.
,, 13, 8 ,,	S.	2	Cloudy	Lights scintillating and undulating rapidly.
,, ,, 10 ,,	S.	1	Fine, moonlight	Lights scintillating.
,, 14, 8 ,,	ESE.	2	Fine, misty	Lights invisible.
,, ,, 10 ,,	,,	2	,,	,,
,, 15, 8 ,,	Calm	0	Overcast	Lights steady.
,, ,, 10 ,,	,,	0	,,	,,
,, 16, 8 ,,	W.	1	Fine, moonlight	Lights scintillating.
,, ,, 10 ,,	,,	2	,,	Lights scintillating and undulating rapidly.
,, 17, 8 ,,	NNW.	1	Fine, foggy	Lights invisible.
,, ,, 10 ,,	,,	1	,,	,,
,, 18, 8 ,,	N.	1	Fine	Lights steady.
,, ,, 10 ,,	,,	1	,,	,,
,, 19, 8 ,,	NE.	2	,,	,,
,, ,, 10 ,,	,,	2	,,	,,

It would appear that an off-shore breeze, or the absence of any breeze, is unfavourable to the phenomenon.—SPENCER C. RUSSELL, Epsom, Surrey.

Exciting Balloon Adventure.

The Hon. Mrs. Assheton Harbord has given in *The Times* the following interesting account of a recent balloon voyage across the Channel to France:—

"I left Battersea Gasworks in my balloon, the *Valkyrie*, 60,000 cubic feet, at 9.45 on Friday night, January 31, to make an attempt to win the Northcliffe Challenge Cup for the longest distance travelled during the present year. Mr. J. F. Pollock accompanied me as pilot, this being his seventh crossing and my third. We had considerable difficulty in getting away owing to the high wind that prevailed; but taking advantage of a momentary lull we cleared a very high gasometer and went straight up to a height of 2500 ft. We took with us 17 45-lb. bags of ballast, four of which we used in the first three-quarters of an

hour. At 10.30 the *Valkyrie* encountered a violent squall, which caused the car to sway to such an extent that we had to hold on to avoid being thrown out. We sighted the coast at 10 minutes to 11, and left it at 11.7, an hour and 20 minutes from the time of starting from Battersea. We were then at a height of 3700 ft. The night was very dark, but we gathered from the bend of the coast that we were leaving the land to the right of Dungeness. In the middle of the Channel we could see the revolving lights on both coasts; and recognising Boulogne, we concluded that we were passing over the French coast near Le Touquet, which we afterwards found to be correct. We sighted the land at 11.20, and reached the coast at two minutes to 12 at a height of 3700 ft., the crossing having taken 51 minutes. The sea crossing was the quietest and the most uneventful part of the voyage, for at 1.30 we experienced strong vertical currents which made the balloon shoot up very rapidly, and when it encountered a downward vertical current it fell with great speed, making a continuous discharge of ballast necessary. There was a good deal of sheet lightning, and the atmospheric conditions were very curious. The car hoop and neck of the balloon seemed illuminated as if by electric light, which, when I rubbed it, made my glove appear alight. At 2 o'clock we encountered a terrific snowstorm, which covered us and half filled the balloon, which was considerably affected by the extra weight thus thrown upon it. Subsequently we again found ourselves rising very rapidly, and after attaining an altitude of 8000 ft. we discovered that we were falling equally rapidly. The discharge of five bags of ballast in four minutes had no effect in checking the descent, and suddenly at a height of 1500 ft. the bottom of the car crashed down on something with great force. The trail rope then began catching in everything it could find, giving the car very violent jerks. We were dashing along at a terrific speed, and the night was so dark that I could scarcely distinguish Mr. Pollock, the roaring of the wind combined with the heavy snow making us extremely anxious, as the last bag of ballast had not the slightest effect on the balloon; and having only three bags left, we realised there was no alternative but to make a descent, and chance where we should land, as we were completely enveloped in darkness. So Mr. Pollock opened the valve, while I crouched low down in the car, feeling rather thrilled at what might happen. Down we crashed with great force straight into some trees. Mr. Pollock ripped at once, but the wind carried us up again, and down we came with the basket overturned. Mr. Pollock shouted out, 'Are you in?' and I called back, 'Yes,' for I was holding on for all I knew, the violent encounters with the trees making it very difficult to avoid being thrown out. At last a tree caught the envelope, causing a large tear, which, combined with the rip, brought us to a standstill. After we had collected our senses we got out and found we were in a dense forest, far away from any habitation. There was nothing for it but to wait till dawn, and conjecture what country we had descended in. At about 6 it became light, so we started off to get out of the forest, and after half an hour's walking we found ourselves on a main road, along which we walked for an hour. At last we discovered a man cutting trees,whom we hailed, and discovered from him we had descended in the department of the Meuse near the small village of Haudiomont. We made him walk back with us to show him where we had descended, and he promised to return with a cart, which he did in three hours. In the meantime we had been discovered by more wood-cutters, who set to work to help us, and with their assistance we packed up the balloon. The envelope being high above us on the trees it was with much difficulty we got it down, and also the trail rope, which was stretched far away on the tree-tops. We also had to collect various pieces of the balloon envelope, which we discovered hanging from branches, on one of which we found the feed pipe, which had been entirely torn off. Unluckily we smashed all our instruments, the first crash quite settling the

statoscope. The drive of ten kilomètres to Verdun took eight hours, as the horses went at a snail's pace, and a remarkably cold drive it was in a bitterly cold wind. If we could possibly have weathered the storm we could have had a tremendously long run, but there was no alternative for us under the circumstances but to descend. A great deal was due to Mr. Pollock for his presence of mind and quick action when every minute was of the utmost importance, for it takes a good deal of nerve to make a descent in a pitch-dark night without the faintest idea of what one will land on. It was a thrilling experience, and, though the distance accomplished will, no doubt, soon be beaten, it was a very sporting run, and one always to be remembered."

Rainfall of the Atlas Lands.

The most complete study yet made of the precipitation conditions of North-West Africa (Morocco, Algeria, and Tunis) is that of Dr. Karl Knoch, which appears in the *Jahresbericht* of the Frankfurt Association for Geography and Statistics (17 Jahrgang, Frankfurt am Main, 1907). It occupies 86 pages, and embodies in a generalised form all the data on the subject at present available. For Algeria, and in a less degree for Tunis, they are fairly extensive, and some of the series of observations extend over a considerable number of years. For Morocco the case is different, though observations have been made at certain stations within recent years, while a general discussion of the climate has been supplied by Dr. Theobald Fischer, to whom Dr. Knoch owes the suggestion which led him to undertake the present work. After some preliminary matter the author proceeds to discuss the distribution of the rainfall in space and time. The most striking fact is the great variation between different parts of the region. As regards the former, it may be said that, taken as a whole, the rainfall diminishes from the coast to the interior, and also from east to west, the most rainy region of all being that of the highlands of northern Tunis, though most of the Algerian Tell is well supplied. An exception to this general rule is formed by the Atlas of Morocco, where naturally the rainfall again shows a marked increase, after falling to a low figure over the outer plateau. Taken as a whole the Atlas region falls within the realm of winter rainfall, with dry or almost dry summer, though this does not hold good beyond a limited distance from the coast. The summer drought is especially pronounced along the whole coast of Algeria and Tunis. On an average, the largest amount of rain falls in January in western Algeria; but farther east, in December.

In Morocco the distribution seems to be somewhat different, so far as can be judged from the still scanty data. In the south there is a small amount of rain even in July and August, the driest months (the most rainy month being November), while farther south they are quite rainless. In this direction the amount of winter rain also shows a relative diminution. In Mogador, *e.g.*, there is a subordinate maximum in March, beside the main maximum in December. With the increase in height as we go inland the summer drought is moderated, while throughout the whole interior the spring is the most rainy season.

A section of the paper deals with the water-supply of the rivers, which varies greatly in different parts of the region and at different times of the year. Most of the rivers reach a very low level during the summer drought unless they are fed from the region of spring rainfall or from melting snows. Morocco, owing to the greater height of the Atlas towards the west, is more favourably placed than Algeria or Tunis in this respect. Another instructive section is devoted to a consideration of the relations of vegetation to rainfall, and this is further illustrated by a vegetation map on tracing paper, which can be placed over the rainfall map. The fact that no regular cultivation is possible where

the precipitation is less than 400 mm. (15·7 ins.) is clearly brought out. A series of tables gives the rainfall statistics for a large number of stations, showing *inter alia* both the mean amounts and the percentages of the yearly total for each month and season.—*Geographical Journal*, December 1907.

Mount Weather Observatory.

The U.S. Weather Bureau during the last few years has founded and equipped the Mount Weather Observatory, which is specifically devoted to research work. It is 1725 feet above sea-level, and is located in Virginia, on the top of the Blue Ridge Mountains, some 20 miles south of Harper's Ferry and 47 miles in a direct line from Washington. It is only 6 miles from Bluemont, the nearest railway station, and is easily reached from that point along an excellent mountain road. It overlooks to the west the entire Shenandoah Valley from Strasburg to Harper's Ferry, while to the east all that portion of Piedmont Virginia between the Blue Ridge and the Bull Run Mountains is in full view. This extensive sweep of valleys, mountains, and plains affords rare opportunities for the study of storm formation and action. This location is satisfactory for the physical laboratory and for the magnetic observatories. For solar work it is as well adapted as any place east of the Rocky Mountains; while for the study of the upper air it is peculiarly well situated, since kite flights can be obtained there almost daily through the entire year.

The *Bulletin of the Mount Weather Observatory*, which will be published quarterly, will contain more or less detailed accounts of the researches conducted at that place. The first number has just been issued, and contains two papers, viz.: (1) "The Methods and Apparatus used in obtaining Upper Air Observations at Mount Weather," by Dr. W. R. Blair; and (2) "The Use of Upper Air Data in Weather Forecasting," by Prof. A. J. Henry (see below).

The Use of Upper Air Data in Weather Forecasting.

Prof. A. J. Henry, who is one of the forecasters of the United States Weather Bureau, during the summer of 1907 had the opportunity of comparing upper air conditions as obtained by kite flights at Mount Weather, Va., with the general meteorological conditions over the eastern part of the United States, as shown by the 8 a.m. daily weather map. The general conclusions which he believes may be drawn from the data thus far collected, are the following:—(1) The air column in the "low" is warmer than in the "high" for such altitudes as were reached by the kites; (2) the region of greatest cold is found in the south-eastern quadrant of the "high"; (3) as the centre of the "high" crosses the meridian of the station, and passes to the eastward, the temperature conditions aloft become more or less unstable, inversions take place, and the rate of decrease of temperature with increase of altitude diminishes.

Occasionally in the kite flights layers of air are met having temperatures higher than those found in layers of less altitude; in other words, the vertical gradient is interrupted, and instead of a fall in temperature with increase in altitude a rise is found. Such breaks in the continuity of the vertical temperature gradient are known as inversions.

Temperature inversions may be classed as follows: First, those which occur in the rear of a "low" or on the immediate eastern front of a "high." Inversions in this region are thought to be due to the circumstance that the warm surface layers of the "low" feel the cooling effect of the "high" a little sooner than the layers at some distance aloft. This assumption follows the suggestion of Mr. Helm Clayton, of the Blue Hill Observatory, viz., that the cold air of the northern portion of the "high" moves more rapidly east-south-east than does the "high" itself, and that, on account of its greater specific weight as compared with that of the air into which it is moving, it sinks

toward the earth's surface in an inclined stratum which reaches the ground in the rear of the "low." This type of inversion has little or no significance to the forecaster, since, ordinarily, cooling in the rear of the "low" proceeds until the upper layers, within the limits of observation at least, acquire a temperature nearly such as is required by the adiabatic rate of cooling for dry air.

A second type of inversion is met when the kites pass from one current of air into another having a different temperature. The existence of a current of warm air flowing along and above a colder one is revealed in this way. Inversions of this nature sometimes afford early indications of the approach of warmer conditions at the surface. The difficulty in properly applying this information at present lies in the fact that the horizontal extension of the warmer current is unknown.

The rate of decrease of temperature with increase of altitude is almost constantly changing, being generally different in the forenoon from what it is in the afternoon. The sequence of changes in this element in its relation to the drift of "highs" and "lows" appears to be about as follows:—In the region of cold, dry winds, which is found on the eastern front of a "high," it approaches closely to the adiabatic rate for dry air, viz., 1° F. in 185 ft., or 1° C. in 100 metres. From this rate, which is maximum, it begins to diminish with the shift of the winds to an Easterly quarter, and the consequent increase in their moisture content. The rate in rainy weather is rather variable, sometimes almost zero up to a height of nearly a mile, and again being much greater. The rate of decrease most frequently observed was about 3°·5 F. per 1000 ft., or 0°·6 C. per 100 metres. The forecasting value of this phenomenon (the vertical temperature gradient) is not yet understood.

Meteorology in the Antarctic.

Dr. W. S. Bruce has received word that the *Uruguay* has returned from Scotia Bay, South Orkneys, bringing with her the party from the Meteorological Station on that island, and having left behind the relief party to continue the work for another year. This relief party was on the *Austral*, which was wrecked, but the party was immediately transferred to the *Uruguay*, which accomplished the journey in safety.—*Scottish Geographical Magazine*, April 1908.

RECENT PUBLICATIONS.

Airships Past and Present. Together with Chapters on the Use of Balloons in connection with Meteorology, Photography, and the Carrier Pigeon. By A. HILDEBRANDT, Captain and Instructor in the Prussian Balloon Corps. Translated by W. H. STORY. London: Archibald Constable and Co. 1908. 8vo. 16 + 364 pp. and plate.

This work gives in an interesting manner a survey of the development of the art of ballooning from the earliest times. The author was a member of the International Commission, which was appointed to consider matters connected with the application of ballooning to scientific ends, and he has worked with Prof. Assmann and Prof. Hergesell. He is able to speak from personal knowledge of what has been done by means of balloons and also by kites to investigate the upper atmosphere.

The work contains more than two hundred illustrations, many of which are of meteorological interest.

Meteorological Atlas of the Indian Seas and the North Indian Ocean. A Series of Weather Charts with descriptive Text, prepared chiefly by W. L. DALLAS of the Meteorological Department of the Government of India, under the direction of GILBERT T. WALKER, M.A., D.Sc., F.R.S., Director-General of Observatories in India. 1908. Messrs. John Bartholomew and Co., Edinburgh. Size 15 × 12 inches.

This Atlas consists of thirty-six charts, which are printed in colours. The first twelve charts show for each month the average conditions of atmospheric pressure, the direction and force of the normal winds, and the sea-currents. Opposite each month short descriptive remarks are given, drawing attention to the changes which have occurred in the weather since the preceding month, and to the most marked meteorological features of the month under review.

The nine charts which follow show the ordinary tracks of storms over the Arabian Sea and the Bay of Bengal for each of the stormy months of the year, and a short account of the principal features of the tracks of storms in the different months is given in the text.

The last fifteen charts of the Atlas exhibit the conditions prevailing over the Arabian Sea and the Bay of Bengal during the existence of typical storms of those seas. These charts not only show the movements of the selected storms over the sea-area from day to day, but exhibit the winds and weather actually recorded by ships traversing the Indian seas during the existence of the storms, and also the areas over which the storm influence extended.

Meteorological Charts of the Southern Ocean between the Cape of Good Hope and New Zealand. Second Edition. Published by the Authority of the Meteorological Committee. Official No. 123. London, 1907.

These charts were originally issued in 1899, and were noticed in the *Quarterly Journal*, 1900, 26, p. 283.

In this second edition the scale of the Wind, Barometer, Air Temperature, and Fog charts have been reduced, as well as that of the charts of the Sea-Temperature Isothermals, to make the publication more handy. On the other hand, the scale of the current charts has been slightly increased, and charts have been added to show the distribution of ice. The work has been carried out under the superintendence of Capt. Hepworth, Marine Superintendent.

Scottish National Antarctic Expedition. Report on the Scientific Results of the Voyage of s.y. "Scotia" during the Years 1902, 1903, *and* 1904, *under the leadership of* WILLIAM S. BRUCE, LL.D., F.R.S.E. Volume II. Physics. Edinburgh, 1907. 4to. 324 pp. and plates.

This volume is devoted almost entirely to the meteorological results of the expedition, which were in the capable hands of Mr. R. C. Mossman. The observations are given *in extenso*: (1) Those taken at sea; (2) at Scotia Bay, April 1 to October 31, 1903; (3) at Omond House, Laurie Island, South Orkneys, November 1, 1903, to February 21, 1904; and (4) at Cape Pembroke, Falkland Islands, 1903-1904.

Mr. Mossman gives a full discussion of the whole of these observations, and the results are shown graphically in a number of coloured diagrams.

Part II. contains a discussion of the magnetic observations by Dr. C. Chree and Mr. R. C. Mossman.

Part III. contains a brief report by Sir G. H. Darwin on the tidal observations.

METEOROLOGICAL LITERATURE.

The following titles of papers bearing on Meteorology have been selected from the contents of some of the periodicals and serials which have been received in the Library of the Royal Meteorological Society. This is not a complete list of all the published meteorological articles, but only shows those that appear to be of more general interest.

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THE ANTICYCLONIC BELT OF THE SOUTHERN HEMISPHERE

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[Read April 15, 1908.]

THREE years spent up and down South Africa during the late war, followed by another period of almost the same length, during which I travelled through the whole of the country from the Cape to the Zambesi, as well as from Durban to Beira, have made me acquainted with the physical features of this vast sub-continent, and enabled me to study the control which the southern anticyclonic belt exercises over its climate. From our President on his return from his visit with the British Association in 1905 the Society received a general description of the country from a meteorologist's point of view.[1] For the visit of the Association Mr. C. M. Stewart, Secretary of the Meteorological Commission, Cape Colony, had specially prepared an article upon the Meteorology of South Africa,[2] and had brought together a great deal of valuable information regarding its rainfall and prevailing winds to assist in the discussion of its climate.

Barometric observations were commenced at the Cape Observatory in April 1841, and at Durban in 1873, and from these monthly means reduced to 32° sea-level and 45° lat. have been compiled and published in the Annual Report for 1905 of the South African Association for the Advancement of Science.[3] In these recent publications, in the annual Reports published by the Observatories of the Cape, Durban, Kimberley, and Johannesburg, with instrumental or eye observations from several hundreds of observers, and in the many valuable isobaric charts which deal with the oceans adjoining South Africa, a very large amount of information regarding South African weather has been collected since 1841

[1] *Quarterly Jour. Roy. Met. Soc.*, July 1906, "South Africa as seen by a Meteorologist in 1905," by H. R. Mill, D.Sc.

[2] *Science in South Africa*, 1905, "The Meteorology of South Africa," by Chas. M. Stewart.

[3] *Report S. A. A. Advancement of Science*, 1906, "The Barometer in South Africa," by R. T. A. Innes, F.R.A.S.

and is now lying waiting to be analysed. Towards this end I contributed two papers, which were read at the meetings of the South African Association at Kimberley in 1906, and at Durban in 1907.[1] The chief interest is found to centre round the movements of the anticyclonic belt and of its component anticyclonic systems.

Progressive Movements of Permanent Anticyclonic Systems in the Northern Hemisphere.

In July 1898 I brought to the notice of the Society the progressive movements of some of the so-called permanent anticyclonic systems of the northern hemisphere,[2] and I called attention to the fact that such systems followed tracks year after year, which were in some years north and in others south of a mean track. For a series of years the tracks appeared to be displaced in a southerly direction, and in the daily synoptic charts the system would be found dominating an area a little south of that which it occupied at the same season the previous year. This would then be reversed and the tracks would be displaced in a northerly direction. The eleven years from 1881 to 1891 were examined in great detail, almost all available daily and monthly synoptic charts being analysed and the tracks laid down upon a chart. The simplest explanation of such a phenomenon was that a real shifting was taking place in the latitude of the anticyclonic belt itself, and this would certainly control the tracks followed by its component permanent systems. But in spite of the mass of charts that were available, no definite conclusion on this important point could be arrived at, and it appeared hopeless to look for one under the unstable conditions of the northern hemisphere, unless some clue to begin upon could be obtained.

At the Bristol meeting of the British Association in August 1898, Mr. Douglas Archibald referred to van Bebber and Köppen's set of twenty types of weather-systems which had recently attracted so much attention. They were the result of an exhaustive examination of synoptic charts of the northern hemisphere, and it was announced that not only do such types recur annually, but that they exhibit a tendency to succeed or to be associated in some cases with one another. The types were identified as belonging to certain seasons, and it was observed that they would at some seasons precede, and at others would follow, those with which they were most closely associated. In this I found strong support for the views I had just previously advanced regarding the progressive movements of the permanent anticyclonic systems, which in the case of the Europasian systems was from east to west in the first half of the year, and from west to east in the second. In some of the cases it was clear that the types which preceded one another as the systems were moving in one direction, succeeded one another as they moved back on the return journey. But this point was not associated by the authors with any progressive movement on the part of the anticyclonic systems, nor did a reference to their original work throw any light upon the important

[1] *Report S. A. A. Advancement of Science*, 1906, "Anticyclones and their Influence on South African Weather," by Col. H. E. Rawson, F.R.Met.Soc., and "Anticyclones as Aids to Long-Distance Weather Forecasts in South Africa" (not yet published).

[2] *Quart. Jour. Roy. Met. Soc.*, July 1898, "Anticyclonic Systems and their Movements."

question whether the latitude of the types was ever found to vary. It was evident that the northern anticyclonic belt was too broken to enable anything like an annual change in its general position to be traced, and that for this we must turn to the southern belt, which is under much more stable conditions owing to its being less interrupted by land.

Seasonal Migration of the Southern Anticyclonic Belt.

The seasonal migration of the southern belt is a real displacement northward and southward, with the sun, of the action-centres of the systems which move within it, and not merely a variation in their intensity. All the isobaric charts of the southern hemisphere agree on this point, and the seasonal variations of the winds over the sea and over the land confirm it. It is well seen in the large-scale *Meteorological Charts of the Southern Ocean between Cape of Good Hope and New Zealand*, published by the Meteorological Council in 1899 for each month of the year. They have been prepared from all available logs of vessels for the years 1855 to 1895, and they include the area between lats. 30° and 60° S. and longs. 10° and 180° E. Owing to their not extending farther north than lat. 30°, the action-centres, which lie wholly within them in the months of January and February when the belt is farthest south, have nearly disappeared northwards from them in April, and cannot be traced at all in May. In October the action-centres reappear from the north, and remain visible throughout November and December. Buchan's isobaric charts of the southern hemisphere, representing the mean monthly pressure for the fifteen years 1870-1884, show that these action-centres have reached as far north as lats. 27° and 28° in July and August.

The effect of the migration of the belt upon a single station in the South Indian Ocean can be inferred from the Mauritius records of barometric pressure.

TABLE I.—Barometric Pressure, Mauritius Observatory, Monthly Means, 1875-1900.

Jan.	Feb.	March.	April.	May.	June.
ins.	ins.	ins.	ins.	ins.	ins.
29·751	29·734	29·769	29·818	29·888	29·964
July.	**Aug.**	**Sept.**	**Oct.**	**Nov.**	**Dec.**
ins.	ins.	ins.	ins.	ins.	ins.
30·008	30·010	29·998	29·939	29·878	29·814

The monthly means for the twenty-six years 1875-1900 show that pressure increases steadily from March to July and August, and falls equally steadily from September to February. The greatest mean variations of pressure occur between the months of April, May, and June, and between September and October, and Buchan's isobaric charts of the southern hemisphere for the period 1870-1884 enable us to interpret this as due to the seasonal progressive movements of the permanent system within the belt. It is approaching Mauritius in its journey westwards during the early months of the year, and is receding from it in the later months as it returns eastwards. These movements will not be discussed in what follows, as the object of this paper is to submit certain facts connected with deviations in the belt's latitude; but they must not be overlooked.

In December 1892 the late Mr. H. C. Russell, F.R.S., the Government Astronomer for New South Wales, brought before the Society[1] the fact that south of lat. 20° S. a series of rapidly moving anticyclonic systems was ever passing across Australia from the westward, following one another with remarkable regularity. The deductions he drew from it did not find favour; but his diagrams of the tracks which the systems followed, and a table of the monthly changes of latitude from March 1888 to July 1892, enable us to trace the migration northward and southward of the belt in which the anticyclones moved. He found that they reached their most northerly latitude in June, and that their mean track was then along lat. 27° 30′. In February their mean track was most southerly, and was along lat. 38° 15′. One of his conclusions, the importance of which will appear hereafter, is given in his own words: "It is our experience that when an anticyclone track is far from the mean, the weather is also far from the mean."

Discrepancies in Isobaric Charts when they have reference to Different Years.

It is a fact well recognised by sailors that the South-east Trades of the South Atlantic are met with much farther north of the equator in some years than in others. Moreover, the various isobaric charts which have been published do not show the action-centre of the South Atlantic anticyclone in the same mean monthly positions when the years to which the charts refer are not the same. If Buchan's charts published in 1869 are compared with those which he made for the period 1870-1884, or if Mohn's charts published in 1879, 1883, and 1903 are compared with those prepared by the Hydrographic Department of the Admiralty from all available logs of vessels for the period 1855-1899, the mean monthly positions of the action-centre will be found to vary very considerably. For example, the following table gives the latitudes between which the centres lie each month, according to Buchan's charts for 1870-1884 and the Admiralty charts for 1855-1899. The latter show no closed centre in July, but pressure extends in a ridge across the Atlantic from east to west with the isobar 30·2 ins. open on the South African side. In September they show two centres not far from one another and of the same intensity, with their axes on the same parallel, a condition which would be looked upon as very exceptional in such daily synoptic charts as those of the North Atlantic for 1882-3.

TABLE II.—Monthly Deviation in Latitude of the South Atlantic Action-Centre.

	1870-1884.		1855-1899.	Isobar.		1870-1884.		1855-1899.	Isobar.
				ins.					ins.
Jan.	Lat. 23½° – 34°		Lat. 22° – 35½°	30·1	July	Lat. 26° – 30°		Lat. 20½° – 34°	30·2
Feb.	,, 26 – 33		,, 25½ – 35	,,	Aug.	,, 25 – 29½		,, 19 – 35	,,
Mar.	,, 24 – 34		,, 22 – 39	,,	Sept.	,, 26 – 30		,, 22 – 34	,,
April	,, 25 – 32		,, 24½ – 38	,,	Oct.	,, 21½ – 34		,, 17 – 37	30·1
May	,, 22 – 33		,, 18 – 34	,,	Nov.	,, 27 – 35		,, 17 – 37	,,
June	,, 24½ – 29		,, 19½ – 31½	30·2	Dec.	,, 21 – 32½		,, 21 – 35	,,

In every month the area covered during the period 1855-1899 is greater than during 1870-1884, which is just what we might expect if

[1] *Quart. Jour. Roy. Met. Soc.* vol. 19, "Moving Anticyclones in the Southern Hemisphere."

the action-centre was in some years north of its mean seasonal position and in others south of it.

Over South Africa an action-centre is found in some of the charts, but not in all, during the months of June and July; while in some it has become established by May and leaves in August; but in others it does not appear till June, and it then remains on till August. Both sets of charts in the following table are made by Buchan.

TABLE III.—Monthly Deviation in Latitude of the South African Action-Centre.

	1870-1884.	1885-1894.	Isobar.		1870-1884.	1885-1894.	Isobar.
			ins.				ins.
May	Lat. 26°–32½°	No centre	30·1	July	Lat. 27°–31½°	Lat. 28°–32°	30·25
June	,, 26–28½	Lat. 27°–32°	30·2	Aug.	No centre	,, 29–33½	30·175

In this table the charts for the short period 1885-1894 show the action-centre in June and July to be occupying a more southerly position than in the longer period 1870-1884. The date when it first establishes itself over the land is easily identified in the records of the Durban Observatory by the exceptionally large and rapid rise which takes place in the barometric pressure; and the regularity with which it appears is indicative of the wonderfully stable conditions which exist in this part of the southern hemisphere. This is shown in Table IV.

TABLE IV.—Establishment on Land of the South African System.

Year.	1885.	1886.	1887.	1888.	1889.	1890.	1891.
Date . .	May 20	May 17	May 15	May 31	June 3	June 9	May 29
Intensity .	30·445	·452	·543	·424	·618	·617	·644
Year.	1892.	1893.	1894.	1895.	1896.	1897.	1898.
Date . .	May 28	May 9	May 29	May 28	May 29	June 2	May 18
Intensity .	30·500	·622	·456	·541	·400	·599	·530
Year.	1899.	1900.	1901.	1902.	1903.	1904.	1905.	1906.
Date . .	May 21	May 29	**June 4**	**June 17**	**June 22**	**June 19**	May 10	May 30
Intensity .	30·597	·421	·587	·541	·534	·614	·482	·632

The years 1901-1904 form a notable interruption to the general punctuality of the system, 1903 showing the greatest departure from the mean date. An analysis of the winds, as the system persists over Durban, gives an indication of the position which it is occupying relative to Durban, and it is noteworthy that the years 1904 and 1905 differ from all the rest in being the only ones in which a North-east wind is recorded. In the southern hemisphere such a wind belongs to the northern part of the system, and the inference to be drawn from this, coupled with its late arrival, is that in these years the system was farther south than usual.

The isobaric charts for the month of July published with Mohn's *Grundzüge der Meteorologie* in 1879, 1883, and 1903, differ materially among themselves. In the edition for 1879 the isobar 765 mm., enclosing the Australian action-centre, touches the north coast there, and passing through the north of Madagascar, goes within 10 degrees of the equator as it crosses South Africa. The same isobar in the edition (third) of 1883 lies 6 degrees farther south over Australia, and 10 degrees farther south over South Africa. The importance of this in connection with the present inquiry will appear later on.

In the *Barometer Manual* published by the Meteorological Council in 1905 isobaric charts are given for the months of January and July, which differ entirely from Mohn's of 1903, or Buchan's for the years 1870-1884. The chart for July shows no action-centre over the Atlantic or South Africa, and the centre over the South Indian Ocean extends 2 degrees of latitude farther north and 4 degrees farther south than shown by Buchan. The Council's chart is compiled from vessels' logs for the years 1855-1899, and this is another instance of the action-centre occupying a much wider area in latitude when the chart has reference to a long period of years.

Testimony of the Winds to Changes in the Latitude of the Anticyclonic Belt.

It might be considered that the discrepancies which have been pointed out could be readily accounted for by the increase in the number of observations and their greater accuracy. But this explanation is insufficient when the percentage frequency of the winds at such observatories as the Cape and Durban are examined and compared for different years. A very real change in prevalence is found to exist, and is so far waiting for an explanation. Mr. C. M. Stewart pointed it out in 1903 as the result of his investigation of the tri-daily observations taken at the Royal Observatory, Cape Town, during 1896-1900.[1] He has compared the percentage frequency of the winds from the eight principal points of the compass during these years with those given by Buchan in the *Challenger* Report for the 18 years 1842-1855, 1862-1865.

TABLE V.—Percentage Frequency of the Winds, Royal Observatory, Cape Town, for 18 Years 1842-1855, 1862-1865 (B), and for 5 Years 1896-1900 (S).

Month.	N.		NE.		E.		SE.		S.		SW.		W.		NW.		Calm.	
	B.	S.	B.	S.	B.	S.	B.	S.	B.	S.	B.	S.	B.	S.	B.	S.	B.	S.
January .	3·2	1·5	0·0	0·3	0·0	0·1	6·4	11·5	**67·8**	**52·9**	3·2	6·7	6·4	4·0	12·9	19·8	No Returns.	3·2
February .	3·6	1·5	0·0	0·0	0·0	0·5	7·1	8·9	**64·3**	**57·8**	3·6	3·4	7·1	3·7	14·3	20·6		3·6
March .	3·2	1·5	0·0	0·2	3·2	0·4	6·4	10·4	**54·9**	**48·4**	3·2	3·5	9·7	4·4	19·3	24·8		6·2
April. .	6·7	2·8	0·0	0·6	0·0	0·6	10·0	13·1	**46·7**	**44·9**	6·7	3·3	10·0	3·6	20·0	22·8		8·4
May . .	9·7	6·9	0·0	0·9	0·0	0·3	6·4	12·5	**41·9**	**32·1**	3·2	3·4	9·7	5·1	29·3	31·5		7·3
June . .	16·7	9·4	0·0	0·9	0·0	0·3	3·3	13·6	**30·0**	26·3	10·0	3·0	13·3	6·7	26·7	**31·6**		8·2
July . .	16·1	14·3	0·0	0·8	0·0	0·2	3·2	13·1	**38·7**	17·8	6·4	2·5	12·9	6·5	22·6	**40·3**		4·5
August .	9·7	10·3	0·0	1·4	0·0	0·2	6·4	11·7	**35·5**	27·0	6·4	2·5	16·1	6·1	25·8	**34·3**		6·5
September.	6·7	5·8	0·0	0·3	0·0	0·3	6·7	12·3	**40·0**	**34·4**	6·7	3·3	16·7	10·1	23·3	24·9		8·4
October .	6·4	4·6	0·0	0·0	0·0	0·0	3·2	10·9	**45·2**	**39·1**	6·4	5·6	19·4	12·6	19·4	23·1		4·1
November .	6·7	3·2	0·0	0·4	0·0	0·4	6·7	10·0	**56·7**	**44·3**	3·3	5·1	10·0	7·3	16·7	25·6		3·8
December .	3·2	1·7	0·0	0·0	0·0	0·3	9·7	15·3	**64·5**	**52·5**	3·2	5·7	9·7	5·5	9·7	16·6		2·4
Year . .	7·7	5·3	0·0	0·5	0·3	0·3	6·3	12·0	**48·8**	39·9	5·2	4·2	11·8	6·3	20·0	26·3		5·4

Mr. Stewart points out that these figures lead to very different conclusions regarding the prevalent winds at the Cape to those drawn by Dr. Buchan. Whereas the *Challenger* results indicate that South is the prevailing direction in every month of the year, this table shows decided indications of a "monsoon" influence during 1896-1900, in that during the winter months of June to August the prevailing direction is North-

[1] *Report of the S. A. A. for Advancement of Science*, 1903, p. 63.

westerly, while it is Southerly during the rest of the year. Both Buchan's and Stewart's figures agree in making the North-west wind more prevalent in the winter than in the summer months, and to be the most frequent wind after the South in every month except December, when the South-east shares it with the North-west. The important point to notice is that Stewart detected a monsoon influence in 1896-1900, which was not traceable in the period analysed by Buchan.

In the annual reports of the Durban Observatory for the 10 years 1885-1894 the percentage frequency of the winds has been calculated each quarter for seven stations within Natal and six stations beyond it. As we have Buchan's monthly isobaric charts of South Africa for these particular 10 years, it is most instructive to follow the seasonal changes in the winds as the belt migrates north and south. It is also evident that in Natal, as well as at the Cape, real changes in prevalence were taking place year by year. In the following table the percentage frequency of the winds at Durban, for the winter half-year April to September, has been compiled from the reports :—

TABLE VI.—Percentage Frequency of the Winds, Durban Observatory, April to September 1885-1894.

	1885.	1886.	1887.	1888.	1889.	1890.	1891.	1892.	1893.	1894.
Calm .	...	...	...	...	16	15	10	3	2	1
N. . .	23	23	21	30	23	23	24	26	22	23
E. . .	24	24	26	22	24	26	25	25	25	25
S. . .	27	19	28	26	23	24	22	21	24	26
W. .	17	15	24	20	14	12	19	25	27	25

This table shows how regular the winds are during the months April to September except those with a Westerly component, whose increased frequency in 1892, 1893, and 1894 marked these years out for special examination. Observations of the winds are recorded twice a day, at 9 a.m. and 3 p.m., at the Observatory, and on consulting the daily records it became apparent that these years were exceptional, not only for the number of entries of a NW., NNW., or WNW. wind during the months April to September, but also throughout the year. There were not many for 3 p.m., and the following table was consequently compiled for 9 a.m. only :—

TABLE VII.—Records of NW., NNW., and WNW. Winds, Durban Observatory, 1890-1905.

Month.	1890.	1891.	1892.	1893.	1894.	1895.	1896.	1897.	1898.	1899.	1900.	1901.	1902.	1903.	1904.	1905.
Jan.	...	1	4	3	...	...	...	...	...	...	...	...	...	...	...	...
Feb.	1	1	8	4	1	...	...	...	...	...	...	...	...	...	...	...
Mar.	2	2	9	4	3	...	1	...	...	1	...	...	...	...	...	...
April	1	4	12	3	8	...	2	2	2	.2	1	1	4	3	1	1
May	4	13	12	10	11	8	7	8	4	8	2	9	7	3	6	3
June	7	11	24	14	15	11	10	10	15	7	5	12	8	11	6	10
July	9	12	15	10	13	11	10	11	7	4	17	12	10	5	8	8
Aug.	3	10	13	12	10	8	5	1	4	...	6	1	4	1	5	1
Sept.	...	5	9	2	1	3	2	...	...	...	1	...	...	...	1	...
Oct.	...	2	2	1	...	2	1	...	...	...	...	...	...	...	...	...
Nov.	...	...	3	3	...	...	...	...	...	...	...	...	1	...	...	...
Dec.	1	1	3	...	...	...	...	...	...	...	...	...	1	...	...	...

In this table the years 1892, 1893, and 1894 stand out above all the others in the number of records from April to September, while

1892 and 1893 are exceptional during the other months of the year as well. In following up this matter in order to try and ascertain its significance it was observed that, in almost every year from 1895 to 1905, one of the earliest appearances of a North-west wind was associated with the same weather characteristics, viz., a barometer reading of over 30·2 ins. and well-defined anticyclonic indications, calm or very light winds, and a clear sky. The same type could be equally easily detected in the years 1890-1894, but it occurred in March or April and not necessarily on the first appearance of the North-west wind.

The following table gives the records of the first arrival of the North-west wind, April 24-29, 1905, and they are typical of all the rest :—

TABLE VIII.—Anticyclonic Type, with NW. Wind, Durban Observatory, April 24-29, 1905.

	Barometer.		Moisture.	Rainfall.	Wind.		Amount of Cloud.		Sky.	
April.	9 a.m. ins.	3 p.m. ins.	Grains. cub. ft.		9 a.m.	3 p.m.	9 a.m.	3 p.m.	9 a.m.	3 p.m.
24	30·089	30·085	6·3	...	Calm	S. v. light	0	3	Clear	Stratus
25	30·228	30·182	6·2	...	NW. light	Calm	0	0	Clear	Clear
26	30·299	30·260	6·0	...	Calm	NE. moderate	0	0	Clear	Clear
27	30·302	30·222	6·2	...	N. v. light	NE. light	0	0	Clear	Clear
28	30·231	30·146	6·2	...	N. v. light	NE. moderate	0	0	Clear	Clear
29	30·159	30·101	6·7	...	Calm	NE. moderate	0	0	Clear	Clear

This is distinctly an anticyclonic type. On application to the Johannesburg Observatory, which was opened in 1905, I obtained from the Director details of the barometric pressure prevailing during this period over South Africa at all stations from Tomba (lat. 15° S.) to Cape Town.[1] The isobaric chart which was specially prepared for April 25 showed an extensive anticyclone lying from east to west across South Africa with an open side towards the east. The highest pressure of the anticyclonic belt had spread from the east westwards in the form of a ridge, *and Durban lay on the southern edge.* The advent of North-west winds at Durban, associated with high pressure, marks the arrival of the anticyclonic belt in the course of its annual migration northwards, and I infer that when this wind is found prevailing in exceptional months the anticyclonic belt is in an exceptional position. In January and December 1891 the North-west wind is recorded with a barometric pressure of 30·253 ins. and 30·346 ins. respectively, and these rare occurrences are followed in the two succeeding years by the exceptionally numerous records of North-west winds which are given in Table VII. The inference I have drawn is that in either 1892 or 1893 the belt was in an extreme northerly position. It will be useful at this point to summarise the arguments that have been used, and the results which have so far been obtained.

Summary.

An examination of the daily synoptic charts of the northern hemisphere led to the conclusion that some of the permanent anticyclonic

[1] I wish to acknowledge the great assistance I have received from Mr. Innes, Director of the Transvaal Meteorological Department; Mr. Nevill, Natal Government Astronomer; Mr. Sutton, Kimberley Observatory; and the members of their Staff. They have given me access to all their records, and afforded me all information which would throw light on the points raised in this paper.

systems had a progressive seasonal movement which did not take place along the same latitude each year, but was in some years north and in others south of a mean latitude. This was noticeable in the years 1881-1891, and was capable of easy explanation if the belt itself in which they moved shifted its latitude from year to year in addition to migrating north and south with the sun. On analysing the isobaric charts of the southern hemisphere the seasonal migration of the anticyclonic belt is found to be accompanied by a real displacement of the action-centres within it to the northward and to the southward. But when the charts are compared great discrepancies are found to exist in the positions of the centres, if the years to which they refer are not the same. Moreover, when they are prepared for a long period of years the action-centres show a much wider displacement from a mean latitude than for a short period. In one case charts which were published in 1879 were considerably modified in 1883, the area of maximum pressure within the belt being shown farther south. These discrepancies cannot be accounted for solely by an increase in data or more reliable methods of observation, for important changes in the percentage frequency of the winds recorded at the observatories have taken place. At the Cape a "monsoon" influence, associated with the winter months of the years 1896-1900, in connection with the North-west wind, is found to exist, which was not traceable in the years 1842-1855, 1862-1865. At Durban a decided increase in the percentage frequency of winds with a Westerly component in winter months of the years 1892 and 1893 is traced to an increased prevalence of the same North-west wind, and it is found to prevail in an exceptional manner during the summer months also. This wind is proved to indicate the arrival at Durban of the south side of the anticyclonic belt, and the inference is drawn accordingly that during 1892 and 1893, when it prevailed throughout both summer and winter months, the south side of the belt was much farther north than usual.

Meteorological Changes in relation to the Belt's Latitude.

The prevalence of winds with a Westerly component is in accordance with all that we know about the south side of the belt as it lies over the oceans. As long ago as Maury's time it was recognised that South-east winds blew out of the north side of the belt of calms, while on the south side "the winds with Westing in them become the prevailing winds, and between the parallels of 35° and 40° S. the North-west and South-west winds contend with equal power for the mastery." In the monthly charts published by the Meteorological Council in 1882, *Charts for Ocean District adjacent to Cape of Good Hope*, which include the area 10° E. to 40° E. long. and 30° S. to 50° S. lat., we see how completely Westerly winds prevail below lat. 40° S. from January to March, and how they are found farther and farther north till they reach their farthest limit in July. The letterpress on the charts says, "Westerly and Easterly winds alternate near the land. In summer Easterly winds, in winter Westerly winds prevail. Southerly winds (SW. to SE.) prevail throughout the year in the north-west corner of the district" (*i.e.* off the Cape), "but they extend farther south in summer than in winter." From this

description of the seasonal variations of the wind we can form a picture of the action-centres of the anticyclonic belt—the calm zone of old days—"vibrating up and down," as Maury expressed it, "with the trade-wind zone, partaking of its motion and following the declination of the sun." If the anticyclonic belt was farther north than usual during the period 1896-1900, the zone of counter-trades with its prevailing North-west wind would reach as far north in June, July, and August as the Cape Peninsula, and we should have in this fact an easy explanation of the increased prevalence Stewart detected in those years.

It is a direct consequence of the anticyclonic belt coming south and lying over the Cape Peninsula (lat. 34° S.), with its Atlantic system not far from the coast, that the Cape has its dry season from September to April. The belt being south of Durban (lat. 30° S.), Natal, Orange River Colony, and the Transvaal have their wet season in these months. When the belt goes north and an action-centre becomes established on land the dry season of these colonies, which begins in May and lasts till August, reaches its maximum, while the wet season prevails at the Cape. This difference in the dry and wet seasons of the two sides of South Africa is one of the most striking characteristics of its climate. The explanation hitherto given has ascribed it almost entirely to the winds, and has overlooked the systems which give rise to the winds. I have already dealt with this in the paper that has been referred to, "Anticyclones and their Influence on South African Weather," and I need not pursue the subject here.

Capt. Campbell Hepworth, in "The Tracks of Ocean Wind Systems in transit over Australasia,"[1] notices that the centres of the cyclonic systems travelled eastward across the South Indian Ocean "on a more polar path during summer months than in the winter." The four diagrams of the tracks of high- and low-pressure systems during the months November 1890 to March 1891, and May to September 1891, which accompany his paper, show very conclusively that the tracks of the cyclonic systems are kept to the southward of the anticyclonic tracks, and migrate north and south with them. In the Admiralty manual, *Africa Pilot*, 1905, for the area lying between long. 10° E. and 40° E., lat. 30° S. and 50° S., it is stated that on lat. 40° S. and southwards the probability of meeting gales is in January 8 per cent, April 10 per cent, July 14 per cent, October 9 per cent. Farther northwards near the South African coast, it is in January 6 per cent, April 6 per cent, July 13 per cent, October 10 per cent. We should therefore expect that in years when the anticyclonic belt was sufficiently north of Durban to admit more low-pressure systems than usual, the rainfall there should be heavier. We have seen reasons for supposing that 1892 and 1893 were two such years, and the following table gives the rainfall each year from 1885 to 1905.

The year 1893 was therefore remarkable for the phenomenal rainfall of 71·27 ins., or 31·90 ins. above the average for twenty-one years. In discussing the meteorology of the year, the Natal Government Astronomer pointed out that the actual rainfall during the rainy season, September to April 1893-4, was 51·95 ins., or 18·85 ins. above the average of the twenty previous years; and that from September to April 1892-3 it was

[1] *Quart. Jour. Roy. Met. Soc.*, October 1892, p. 34.

46·96 ins., or 13·86 ins. above the average. To find anything approaching such a rainfall it was necessary to go back to the years 1874 and 1875. He concludes as follows: "All things considered, it is probable

TABLE IX.—Rainfall in Inches at Durban Observatory, 1885-1905.

Year	1885.	1886.	1887.	1888.	1889.	1890.	1891.	
	ins.	ins.	ins.	ins.	ins.	ins.	ins.	
Rainfall	34·48	31·79	31·87	37·74	29·54	32·91	45·45	
Year	1892.	1893.	1894.	1895.	1896.	1897.	1898.	
	ins.	ins.	ins.	ins.	ins.	ins.	ins.	
Rainfall	38·37	71·27	37·27	51·50	39·63	34·39	42·48	
Year	1899.	1900.	1901.	1902.	1903.	1904.	1905.	Mean.
	ins.	ins.	ins.	ins.	ins.	ins.	ins.	ins.
Rainfall	28·75	27·24	55·54	41·18	35·66	34·72	44·95	39·37

that the excessive rainfall of the seasons 1892-93 and 1893-94 may have had its origin in the abnormal disturbances which appear to have taken place in the Antarctic regions during the years 1891-93, which resulted in great masses of ice having been driven north as far as 40° S. lat. *The probable effect of this would be to throw the northern border of the great southern rain-belt into close proximity to the south-east coast of Africa, so that outlying portions might easily have impinged thereupon, and then given rise to this heavy rainfall.*" He returns to the same subject in his report for 1896. "The same meteorological conditions are now prevalent as in the years 1892-93, and it appears probable that the same causes have been at work. . . . *All this points to the close approach of the great southern cloud-belt, which seems to have shifted far further north than its usual range.* In the year 1893 the same thing occurred, owing to some great disturbance in the Antarctic having broken up the icefields, and driven great masses of ice far towards the north." Again in the report for 1897 he writes: "Unusually heavy rainstorms appear to have occurred on the south-east coast, as at Port Elizabeth and St. John's, *but they have not reached so far north as Natal.* It is true that, as anticipated, the great southern rain-belt has been forced far north of its usual limits, but in a direction too far east to impinge on the coast of Natal; hence the absence of any great rainstorms similar to those of the year 1893, such as might otherwise have been expected." The portions I have italicised strongly support the hypothesis that the southern anticyclonic belt was far north in 1892-3, and that after those years it was returning south. In 1897 it was preventing the rain-belt from reaching so far north as Natal, but permitting it to impinge upon and bring heavy rainstorms to stations farther south.

Variations of Barometric Pressure in relation to the Belt's Latitude.

It is quite in conformity with our view of the northerly position of the anticyclonic belt in 1892 and 1893 that the annual mean pressure for the former year at Durban was the absolute lowest of the whole series 1873-1905, and for the latter year the ninth lowest.

But if the belt shifted its latitude and in doing so controlled the tracks of the anticyclonic systems which are known to be ever travelling from west to east within it, besides determining the latitude of the more permanent action-centres, the passage of the belt north and south must have left its trace upon the mean barometric pressure of the stations it

passed over. All the inquiries I made from stations south of lat. 26° went to prove that after 1894-5 there was a distinct change in the weather they experienced: it was more anticyclonic. In Natal it culminated in the year 1899. In a discussion regarding the rainfall of the Indo-oceanic region during 1895-1902, which appeared in *Nature* at the end of 1904 and beginning of 1905, Sir John Eliot referred to the eastern half of South Africa as having had heavier rain than usual during 1892-1894, while it was "steadily in defect during the five years 1895-1899, and was specially deficient in 1897 and 1899." Mr. J. R. Sutton, of the Kimberley Observatory, in the same correspondence stated that the percentage of rainfall during 1899 had been 64 per cent in the eastern district of the South African coast, and 87 per cent in Natal. In Table IX. the rainfall at Durban appears as nearly 11 ins. below the average, and in the report for the year it is said to be the lowest recorded at Durban since 1878.

The mean annual pressure for the year 1899 at Durban was also phenomenally high. And here we come to the first of a series of coincidences, if they are to be regarded as such, in connection with the hypothesis that the belt reached a northerly position in 1892 and 1893, and then returned southwards. The Durban observations show that six years before 1893 and six years after 1893 the two highest annual means occurred which have ever been recorded. The following are the mean monthly readings for the years 1887 and 1899 which are given in *The Barometer of South Africa* to represent the barometric pressure at Durban :—

TABLE X.—Mean Monthly Readings of Barometer at 9 A.M., Durban Observatory.

Year.	Jan.	Feb.	March.	April.	May.	June.	
	ins.	ins.	ins.	ins.	ins.	ins.	
1887	29·988	30·023	30·077	30·145[5]	30·207[2]	30·313[2]	
1899	29·950	29·975	·054	·148[4]	·276[1]	·328[1]	
1873-1905	29·973	30·005	·048	·096	·135	·223	
Year.	**July.**	**Aug.**	**Sept.**	**Oct.**	**Nov.**	**Dec.**	**Mean.**
	ins.	ins.	ins.	ins.	ins.	ins.	ins.
1887	30·222	30·154	30·273[1]	30·102	30·093[1]	29·997	30·133[1]
1899	·253	·156	·186[3]	·067	·078[3]	·983	·121[2]
1873-1905	·235	·195	·158	·093	·025	·992	·098

Note.—1, 2, 3, 4, 5, 8 are the highest, second, third, etc., highest of the series 1873-1905.

The mean annual reading for 1887 was thus the highest, and for 1899 the second highest ever recorded. The mean monthly readings for May and June 1899 were the highest, and for May and June 1887 the second highest; for April 1899 the fourth, and for April 1887 the fifth highest; for September 1887 the highest, and for September 1899 the eighth highest; for November 1887 the highest, and for November 1899 the third highest.[1] The close resemblances running through the individual months, as well as in the two years as a whole, can only be accounted for by the hypothesis that the anticyclonic belt occupied the same relative position to Durban in both years, and the very high pressure which

[1] It must be remembered that the range of the barometer in these latitudes is very small. The readings are only taken at 9 a.m. and 3 p.m. at Durban, and the greatest range that has been recorded since the Observatory was opened amounts to 1·452 ins. The annual mean for 1887, as determined by the readings taken at 9 a.m. and 3 p.m., is 30·133 ins., and for 1899, 30·129 ins., without being reduced to gravity of lat. 45° as in Table X.

prevailed indicates that its mean position for the year must have been very close to the latitude of Durban. Table IX. shows that 1887, like 1899, was deficient in rainfall, amounting to almost 8 inches, and the report for the year states that this was the case throughout the colony. It also appears from the reports that from 1886 to 1889 the number of thunderstorms showed a great decrease at all the large towns in Natal, in marked contrast to the large number in 1890 and following years. The point was specially commented upon by the Government Astronomer.

From these facts I draw the first definite conclusion regarding the position of the anticyclonic belt in any particular years, viz., that in 1887 and 1899, during the months of April and September, its central axis lay approximately along lat. 30° across South Africa, and that it migrated north and south of this position with the sun; further, that in 1893 the central axis reached its farthest northerly point.

Determination of the Extreme and Mean Positions of the Belt.

It is important to ascertain whether the change in the belt's latitude is progressive and cyclical in its character, and in what year the most southerly position was reached. Seamen have long held that the Belt of Calms lay between lat. 30° and 35° S. and migrated north and south of this with the sun, but South African meteorologists have, as a rule, given little attention to the existence of the belt as it crosses the land. In the paper which was specially prepared for the British Association upon the meteorology of the country the word "anticyclone" occurs very seldom, if at all. There is a notable exception, however, to this in the annual reports of Mr. Nevill, the Natal Government Astronomer, from whose Durban observations I have drawn so much. In 1893, when discussing the phenomenal rainfall of the year, he remarked: "Natal is on the border of a great southern anticyclonic belt, and it would appear that it is the position and condition of this belt which mainly regulates the climate of Natal. . . . As soon as the laws governing the motion and physical condition of this belt have been approximately determined, so that from a knowledge of its character in the past year there can be ascertained its probable nature in the coming year, then this knowledge can be applied to predicting the probable character of the coming season in the different districts of Natal." His reports show that the idea of a moving zone, which was sometimes much farther north than at others, is often in his mind, and that he had hopes that something would be found out regarding its movements, as the conditions governing the variations in weather over the southern hemisphere appeared to be much simpler, and less liable to extraneous disturbances, than those regulating the variations in the northern hemisphere. I shall return to this again.

But though there is no analysis of the belt's movements to help us, some valuable records of droughts and exceptional rainfalls have been compiled and discussed. In 1889, Mr. D. E. Hutchins, the Conservator of Forests, Cape Colony, who has done so much to assist in tracing any connection that there may be between the meteorology of South Africa and of India, published his *Cycles of Drought and Good Seasons in South Africa*, which supports in a very remarkable way the view that the belt's movements are not only progressive, but cyclical in their character. The

chief object of his inquiry was to test Meldrum's Cycle and the Sunspot theory, by analysing all the special droughts and rainfalls which he could find recorded. He was able to find one which went back as far as 1622. But after endeavouring to fit them in he was unable to find a place for certain exceptional rainfalls in the Cape Peninsula even by making allowances for "Irregular Mitigation" and "Cyclical Mitigation" in their cases. He was forced to adopt another cycle altogether, to which he gave the name of the "Storm Cycle," with a period of 9·5 years, or by going back to 1622 the more accurate one of 9·43 years. The rainfall curve which he gives for the Cape Observatory for the years 1841 to 1888 is, in his opinion, convincing proof of the existence of a 9·5-year cycle over the south-western districts of South Africa, which does not extend, however, to Natal and the east. He discusses the rainfall at several stations along the latitude of about 33° 30′, and detects the storm cycle in them readily; but when he comes to Aliwal North, lat. 31°, he remarks that this station exhibits serious anomalies. "The eastern rainfall," he writes, "differs primarily from the Atlantic rainfall in being influenced by the storm cycle only in the matter of wind." He finds that at eastern stations the cyclical phenomena are materially different, and show little or no connection with western stations. Grahamstown marks the limit to which the cyclical rainfall extended eastwards, and I would call attention to the abrupt trend to the north-east which the coast line takes not far from this station.

The storm-cycle years of the south-west district of South Africa are of great importance to us at this point of our inquiry. Mr. Hutchins states them to be: 1850, 1859, 1869, 1878, and 1888. All these years stand out prominently on the rainfall curve as years of maximum rainfall. I will only give details of the two periods 1853-1859 and 1872-1878 as typical of the whole series.

TABLE XI.—Rainfall at Royal Observatory, Cape Town, 1853-1859 and 1872-1878.

Year.	1853.	1854.	1855.	1856.	1857.	1858.	1859.
	ins.	ins.	ins.	ins.	ins.	ins.	ins.
Rainfall	21·23	20·06	24·58	19·48	22·04	24·28	36·73
Year.	1872.	1873.	1874.	1875.	1876.	1877.	1878.
	ins.	ins.	ins.	ins.	ins.	ins.	ins.
Rainfall	29·33	23·70	26·20	25·72	26·65	35·57	41·03

In this table the corresponding years of the 19-year period are brought together, and the fluctuations in the rainfall, as it rises to a maximum in the storm-cycle years 1859 and 1878, are well seen. The storm-cycle year 1888 was one of exceptionally heavy rainfall, and, with 1889, is distinguished by Buchan, in his analysis of the Cape rainfall from 1841 to 1894, as being in a great measure the cause of the pentade 1886-1890 being one of the two wettest pentades of the series.

But the conclusion that has been arrived at is, that in 1887 the anticyclonic belt was over lat. 30° and was going north, so that in 1888 it lay just to the north of this latitude. In 1899 it was once more over lat. 30° returning south, and consequently in 1898 it was in the same position as it was in 1888. If the movement of the belt is progressive, a cycle of 9·5 years will exactly coincide with and explain the

belt's northerly position in 1893; and it will travel to its most southerly position, and return to that occupied in 1888 and 1898 in another 9·5 years. *The storm-cycle years detected by Mr. Hutchins are those in which the belt occupies its mean cyclical position just north of lat.* 30°. But if, when it is in this position, stations near lat. 34° S. experience great rainstorms, it would be only natural that, when it is far north, southern stations occupying the same relative position should also have the same great rainstorms. The phenomenal rain experienced by Durban in 1893 is an indication that the belt was in that year as far north of Durban as it was north of the Cape Observatory in the storm-cycle years. Durban's storm-cycle years should therefore be 1893, and years at intervals of 19 years before and after it. The following table gives the actual rainfall experienced in such years at Durban as far back as records exist:—

TABLE XII.—Phenomenal Rainfall at Durban Observatory.

Year.	1855.	1874.	1893.	Mean for 21 years.
	ins.	ins.	ins.	ins.
Rainfall	82·82	55·06	71·27	39·37

The exceptional rainfall of 1874 and 1893 has already been referred to, and as regards that of 1855 Mr. Hutchins says that it was heavy all over the eastern part of South Africa as well as over Durban, where it was heaviest. These years may therefore be correctly described as Durban's storm-cycle years, and the eastern rainfall and the western are equally controlled by the position of the anticyclonic belt. Just as in 1892 the annual mean pressure at Durban was the lowest ever recorded, so in 1873 it was the next lowest. For 1854 we have no records.

The clue given by the storm-cycle years discovered by Mr. Hutchins has led to the second definite conclusion regarding the annual changes in the belt's latitude. In 1888 and in each alternate 9th and 10th year before it, the belt lay a little north of lat. 30°, in its mean cyclical position; and north of this, good reasons exist for believing that its entire oscillation up and down was a regular progressive movement. If this was continued south of the mean position and was of a similar character, it ought to be possible to determine the position it occupied in 1883 or 1884, when, according to the cycle of 9·5 years, it was in its most southerly position. From this the extreme range of the belt might be obtained approximately.

Amongst the droughts of South Africa recorded by Mr. Hutchins, that of 1882-1885 over the south-western districts and the Cape Peninsula holds a prominent place. He writes of it, "Thus the drought (ending with 1885) is one of the severest that have occurred in recent years in South Africa . . . it lasted for the considerable length of 4 years . . . it broke up in the spring (at the end) of 1885"; and he records that in 1884 there was a general dying out of the black ironwood trees in the district. As far north as King William's Town (lat. 33°) he found that the drought broke up by the end of 1885; but he specially mentions that at Aliwal North, which is on the same meridian, but in lat. 31°, it did not break up till 1887. This is the year when the belt had reached lat. 30° and was

going north, and we should therefore expect the drought to continue at lat. 31° until the belt had passed. The mean barometric pressure for the year 1884 at the Cape Observatory was exceptionally high, being the fifth highest of the series 1841-1905, whereas that for 1883 was about the mean. We therefore conclude that the belt was in its most southerly position, not far from the latitude of the Cape Observatory (lat. 34°), in 1884, and that it took the same length of time to rise from that latitude to its mean position in 1888 as it took to reach its most northerly position in 1893, viz., 4 to 5 years.

This can easily be put to the test, for in 1850 and 1869 the belt was in the same mean cyclical position as in 1888, and 4 to 5 years previous to these dates it would be occupying the same southerly position relative to the Cape Observatory and the Cape Peninsula as in 1884. We should therefore expect to find that similar meteorological conditions prevailed. From Buchan's analysis of the Cape rainfall from 1841 to 1894 it is seen that he points out the years 1864, 1865, and 1866 as the three driest consecutive years of the 54, the rainfall for 1865 being over 10 inches below the mean, while Mr. Hutchins gives the whole period from 1863 to 1868 as one of drought over this district. Similarly the rainfall of 1845 is given by Buchan as 8 inches below the mean, and Mr. Hutchins records a drought round 1845 which he describes as most intense in 1844. Livingstone in his *Travels* also mentions this drought as most severe, and lasting from 1842 to 1846. The barometric pressure for the years 1845, 1865, and 1884 is as follows:—

TABLE XIII.—Barometric Pressure, Royal Observatory, Cape Town, Monthly Means, 1845, 1865, and 1884.

Year.	Jan.	Feb.	March.	April.	May.	June.	
	ins.	ins.	ins.	ins.	ins.	ins.	
1845	29·951	29·933	30·007[2]	30·055[6]	30·082	**30·230**[1]	
1865	·963[5]	·927	29·934	·022	·054	·208[3]	
1884	·945	·917	·963	29·984	·054	·207[4]	
1841-1900	·923	·922	·956	30·013	·057	·128	
Year.	**July.**	**Aug.**	**Sept.**	**Oct.**	**Nov.**	**Dec.**	**Mean.**
	ins.	ins.	ins.	ins.	ins.	ins.	ins.
1845	30·162	30·184[4]	30·050	30·054	30·011	29·964	**30·057**[1]
1865	·121	·120	·062	29·991	**·061**[1]	·925	·032
1884	·224[3]	·143	·107	30·035	·018[10]	·953	·046[5]
1841-1900	·157	·124	·096	·037	29·989	·948	·029

Note.—1, 2, 3, 4, 5, 6, 10 are the highest, second, third, etc., highest of the series 1841-1905.

From this table we learn that some exceptionally high pressures occurred in each of the years, those for the month of June being the first, the third, and the fourth highest for the 65 years; and the annual means for 1845 and 1884 the highest and the fifth highest respectively. If the inquiry is extended to 1903, the next year in which the belt reaches its most southerly position, exactly the same anticyclonic conditions are found to prevail at the Cape. In the Meteorological Commission's *Report* for this year it is described as "one of exceptionally severe drought lasting throughout the year, unusually low mean temperatures, long-continued and severe frosts, and a fairly high percentage of cloud." The mean annual pressure was the ninth highest, and the means for February, March, and November, the first, seventh, and fourth highest of the 65 years.

All these facts support the view that in 1884 the belt lay approximately over lat. 34°, and as it was found in 1888 lying a little to the north of lat. 30° its change of latitude amounted to about 4½°, or 1° of latitude a year. Its range in 9·5 years would therefore be 9½°, and in 1893, when it reached its extreme northerly position, it would lie approximately over lat. 24½°. In Buchan's isobaric chart for July, which he published in 1869, the action-centre is shown centrally placed over lat. 24°, and this is the most northerly position I have found it to occupy in any of the charts.[1]

The following table gives the years in which the belt reached its extreme northerly and southerly and mean positions since barometric records were commenced in South Africa, and it summarises the analysis that has been made of its cyclical changes of latitude.

TABLE XIV.—Cyclical Changes of the Belt's Latitude and Years of reaching its Extreme and Mean Positions.

Anticyclonic Belt.	Latitude.	Years.	Interval.
Extreme Northerly Position	24½° S.	1855, 1874, 1893	19 years
Mean Position . . .	29½° S.	1850, 1859, 1869, 1878, 1888, 1898	9·5 ,,
Extreme Southerly Position	34° S.	1845, 1865, 1884, 1903	19 ,,

This table should only be regarded as a first attempt to determine the positions of the anticyclonic belt as it performs its double oscillation in a period of 19 years. But it explains in a simple manner and correlates all the principal meteorological features which have been referred to in this inquiry.

1. Isobaric charts must necessarily differ when they do not refer to the same years. Those which include a long period, such as from 1855 to 1899, are giving, the table shows us, the mean pressure resulting from two complete oscillations and a half of the belt, and the action-centres will cover a wide area from north to south, as Table II. showed to be the case. In Table III. the centres in June and July were found occupying a more southerly mean position in the period 1885-1894 than in 1870-1884. We now see that during the latter period the belt travelled twice over the latitudes north of its mean position and only once over those south of it, whereas during the 10 years 1885-1894 the belt was making practically one journey from south to north. The change in the latitude of the belt which Mohn's charts indicate to have taken place between 1879 and 1883 is in accordance with Table XIV., which shows that the belt was moving south from 1878 to 1884.

2. The examination of the winds at the Cape Observatory during the years 1896-1900, as compared with those for 1842-1855, 1862-1865, led to the detection of an increased prevalence of North-west wind in the former years, and of a monsoon influence which was not traceable in the latter. Table XIV. shows that from 1896 to 1900 the belt was always much to the north of the Cape latitude, and that the North-west wind of its southern edge would necessarily prevail to a great extent in the months of June-August. During the periods 1842-1855, 1862-1865, the

[1] In Clement Ley's *Cloudland* (published 1894) the isobaric chart shows the action-centre in a similar northerly position. His isobaric charts of 1879 and 1894 deserve more consideration than they have received.

belt was for 12 years out of the 18 south of its mean latitude, and this would lead to the monsoon influence being masked.

At the Durban Observatory the great prevalence of North-west wind in 1892-1894 and the decrease in 1902-1904 find a ready explanation in Table XIV., which shows that the belt was in its extreme northerly position in 1893, and in its extreme southerly position in 1903. The lateness of the establishment of the South African system on land in 1901-1904, which is pointed out in Table IV., and the occurrence of North-easterly wind at the same time, are just what would result from the belt occupying its extreme southerly position in those years. In connection with this point it is significant that in the *Meteorological Charts of the Southern Ocean between Cape of Good Hope and New Zealand*, which cover the long period from 1855 to 1895 and include two complete double oscillations of the belt, an action-centre within an isobar of 30·3 ins. is found in July south of lat. 30° and to the south-east of Natal. Nothing similar appears on any charts covering a short period. As the belt persists for some time over the same area during the end of its oscillation, it is only to be expected that charts for a long period should show a centre in such a position.

3. The important change in the latitude of the southern cloud-belt during the years 1893 to 1897, which was detected by the Natal Government Astronomer to have shifted far farther north than its usual range, is now seen to be directly connected with a similar shifting of the anticyclonic belt. This leads to the inference that the whole of the zones have a cyclical progressive movement similar to that of the belt.

4. The exceptionally heavy rainfall and the severe droughts which have occurred both in the south-western and in the eastern districts of South Africa are all found to be related to the position of the belt at the time, and the necessity for considering the eastern rainfall to be primarily different from the Atlantic rainfall is shown by Table XIV. to have no foundation in fact. The cause of exceptional barometric pressure is also traceable to the cyclical progressive movement of the belt.

The hypothesis that the belt is always changing its latitude appears to be the clue to South African meteorology, and on turning to Mr. Russell's conclusions regarding that of Australia there seems to be a cyclical variation of the belt there also, which corresponds very closely with that which is given in Table XIV. He was led to advance the theory that there is a general periodic recurrence of seasons every 19 years, and that during every cycle of 19 years there are two periods of good seasons, and two periods of bad seasons, due to droughts, besides minor fluctuations. The Natal Government Astronomer, in his report for 1896, has analysed and reduced to tabular form the seasons experienced in Australia from 1872 to 1896, and has compared them with those of Natal with a view to ascertaining whether they are the same for both districts. Good seasons are those in which good rains fell, and bad seasons those in which droughts were experienced, and the comparison is so confirmatory of the views that have been advanced in this paper, that I reproduce the table as he gives it, and the conclusions which he draws from it in his own words. I have already referred to his frequent mentions of, and belief in, the shiftings of the anticyclonic

and cloud belts over Natal. In the following table the rainfall is that of the whole wet season, from about the end of August to the middle of May.

TABLE XV.—Periodic Recurrence of Seasons in Australia and Natal.

Season.	Character in Australia. According to Theory.		Character in Australia. As Experienced.	As Experienced in Natal. Rainfall. ins.	As Experienced in Natal. Character.	Remarks.
1872-3	Good		Good	47·39	Good	
1873-4	Good		Good	50·53	Good	Favourable
1874-5	Drought		Bad	49·92	Good	Favourable
1875-6	Drought	Drought	Bad	53·02	Good	
1876-7	Drought		Bad	33·15	Bad	
1877-8	Average		Good	34·07	Bad	Drought
1878-9	Good	Favourable	Good	34·05	Bad	Drought
1879-80	Average		Bad	47·32	Good	
1880-1	Drought		Bad	36·77	Average	
1881-2	Good		Good	34·64	Bad	
1882-3	Average		Good	41·73	Average	
1883-4	Drought		Bad	39·57	Average	
1884-5	Drought	Drought	Bad	39·10	Average	
1885-6	Drought	Drought	Bad	39·78[1]	Average	
1886-7	Drought		Good	28·42	Bad	
1887-8	Average		Bad	34·32	Bad	Drought
1888-9	Good		Good	34·26	Bad	Drought
1889-90	Good		Good	28·83	Bad	Drought
1890-1	Average	Favourable	Good	42·38	Average	
1891-2	Average		Bad	30·85	Bad	
1892-3	Good		Bad	55·98	Good	
1893-4	Average		Good	56·60	Good	Favourable
1894-5	Drought	Drought	Bad	54·81	Good	Favourable
1895-6	Drought	Drought	Bad	36·17	Average	

[1] An arithmetical error has been corrected.

The Natal Astronomer writes with regard to this table: "It will be seen that the character of the seasons as experienced in Australia accords fairly well with the theory . . . but that the Natal seasons are by no means in accord with those experienced in Australia, and the theory as set forth does not correctly indicate the value of the Natal seasons. If there be any connection between the characters of the Natal and Australian seasons such as must be the case if the theory be correct, it must be *that there is an interval of one or more years between the corresponding phases of the cycle as manifested in Natal and Australia.* On careful comparison it will be seen that there is some ground for such an idea, and that the Natal cycle follows the Australian cycle at an interval of two or three years. Thus the minor Australian drought of 1874-1877 was followed two years later by the Natal drought of 1876-1879; and the major Australian drought of 1883-1887 was followed three years later by the Natal drought of 1886-1890." The words I have italicised direct our attention to the relative latitude of Natal to the extreme positions of the belt in 1874-1877 and 1883-1887, when Australia experienced its droughts. If we refer to Table XIV. we see that all the droughts in Australia correspond with the period when the belt was at the extreme end of its oscillations, and Mr. Russell's theory probably rose out of the existence of the belt's double oscillation over Australia. The droughts in Natal, as we have already seen, occurred as the belt passed to and fro over the country. In the Natal report for 1893 the Government Astronomer, when discussing

Mr. Russell's views regarding a 19-year cycle, having two periods of good and bad seasons, refers to the southern anticyclonic belt and writes: "As the position of this belt probably is cyclic in character, with a period approaching 9 years or a multiple thereof, a knowledge of its position and condition for the preceding years will afford the means for judging of its probable character for the coming year and thus for predicting the nature of the coming season. If further investigation, founded on the comparison of the observations made in Natal with those made at the other observatories of the zone, lead to the confirmation of these results, then just as it will be possible to utilise the observations made here to give timely warning to the Australian colonies of the approach of atmospheric disturbances, so in turn will it be possible for us to receive early warning of approaching storms from either Australia or South America." He never reverts to this cyclic motion of the belt again, but this testimony to the correctness of the views that have been advanced, which suggested themselves to the writer quite independently, when analysing the movements of anticyclonic systems in the northern hemisphere, is of the greatest value and importance.

Cyclical Changes in Latitude are not confined to the Southern Anticyclonic Belt.

Such a change in the latitude of the southern anticyclonic belt, amounting probably to 9° or 10° of latitude, must effect some great alteration in that of the equatorial belt as well. In the reports recently published by the Director of the Egyptian Survey Department the movements of the equatorial rain-belt and the rainfall which results over the Upper Nile basin are gone into in great detail. He points out the connection which exists between the two, and gives the following table of the ratios of the Nile floods each year of the period from 1869 to 1905, to the mean flood during the 34 years 1869-1903.

TABLE XVI.—Ratios of Annual Nile Floods to Mean Flood.

1st Series.	1869.	1870.	1871.	1872.	1873.	1874.	1875.	1876.	1877.	1878.	1879.	Remarks.
Floods	1·18	1·23	1·05	1·11	0·84	**1·26**	1·10	1·09	0·70	1·25	1·14	In excess
2nd Series.	1880.	1881.	1882.	1883.	1884.	1885.	1886.	1887.	1888.			Remarks.
Floods	0·98	0·93	0·84	1·04	0·83	0·99	0·91	1·19	0·72			Deficient
3rd Series.	1889.	1890.	1891.	1892.	1893.	1894.	1895.	1896.	1897.	1898.		Remarks.
Floods	1·00	1·12	1·01	1·20	0·99	**1·22**	1·15	1·06	0·89	1·07		In excess
4th Series.	1899.	1900.	1901.	1902.	1903.	1904.	1905.					Remarks.
Floods	0·63	0·89	0·87	0·63	0·89	0·75	0·65					Deficient

In this table the period 1869 to 1905 is seen to divide itself quite distinctly into four series. The first series, 1869-1879, consisted of floods which were in excess; the second series, 1880-1888, of those which were below the average of the thirty-four years; the third series, 1889-1898, of those which were again in excess; and the fourth series, 1899-1905, of those which were deficient. On referring to Table XIV. the first and third series are found to correspond with remarkable exactness to the years when the southern anticyclonic belt was north of its mean position, while the second and fourth series contain nothing but years when the belt was south of it. I may remind you that the years of the belt's

mean cyclical position are the storm-cycle years discovered by Mr. Hutchins, and not years which I selected in any way.

As Sir John Eliot has already pointed out a connection between the Nile floods and the rainfall in India, and Sir Norman Lockyer has demonstrated that both of them have a relation to the periods of maxima and minima sunspots, there are good grounds for thinking that both the northern and southern anticyclonic belts move in harmony with one another, and in consequence of an external force.

If we wish to find an analogy for such a shifting in the latitude of our belts we have only to turn to the planet Jupiter. Since 1891 the Jupiter section of the British Astronomical Association has been investigating the movements of the belts of Jupiter, and has established conclusively that they shift their latitude. The annual reports find analogies to our terrestrial trade-winds, and frequently refer to rifts in the atmosphere resembling "cyclones" and to the "winds" and clouds of Jupiter. A large number of drawings of the planet's disc accompany the reports, and the shifting of the two important bands on each side of the equatorial band can be followed during the course of each apparition, in some years closing in upon the band, and at others opening out from it. In 1898 they are to be found closer to one another than in any other year from 1891 to 1904, and for some portion of the apparition they entirely obscure the equatorial band. After 1898 they move outwards to positions very similar to those they occupied in 1891. It is significant that in the year 1898 Jupiter was farthest from the sun, and this fact may have an important lesson contained in it for us. For the natural inference would be that the periods of maxima and minima sunspots would affect the latitude of our belts in a similar manner, and give rise to periodic variations in our weather such as have been discovered. It is reasonable that this should be the case, but Mr. Hutchins' examination of the sunspot cycle demonstrated that so far as South Africa was concerned the storm cycle of 9·5 years was more marked in the records than that of the sunspots. In some cases the latter was mitigated, and in others masked altogether by the former. It would almost appear that some other cause, not yet discovered, must be sought for to account for such changes in the belt's latitude as have been traced to be taking place in South Africa. In the previous inquiry into the movements of some of the permanent anticyclonic systems in the northern hemisphere, the conclusion was arrived at that between 1881 and 1891 a definite change took place in the latitude of their tracks. The present paper suggests, if it does nothing more, that in the year 1884 the southern anticyclonic belt reached its most southern position and began to come north again.

The whole matter certainly merits our attention, and appears to demand further investigation.

DISCUSSION.

Mr. F. C. Bayard inquired whether there was really an anticyclonic belt round the southern hemisphere, or whether it was a series of anticyclones without any belt, running east and west, which took a definite path one time, and another definite path another time.

The President, Dr. H. R. Mill, said that he wished to say how highly

he, personally, had appreciated Colonel Rawson's paper, and the extremely clear way in which the various points were set forth. When they considered such phenomena as temperature or rainfall they were dealing with things influenced by a great variety of causes, but the distribution of atmospheric pressure was the determining cause of the whole range of weather, for it had the power of guiding the systems which produced precipitation and gave rise to changes of temperature. He believed that the variations of rainfall from year to year over the British Isles must be accounted for by some difference in the direction of the paths of the pressure systems which passed over the land. There had recently been a series of consecutive years, when one strip of country, in the east of England, was extremely dry, and there seemed to be no possible explanation of this except a divergence from the normal direction of the low-pressure systems as they crossed the country. Colonel Rawson had the advantage of dealing with a region, the observations from which had not yet been subjected to much study and theorising, but it was one in which the sequence of phenomena seemed to be both simpler and more regular than in Europe, and the outcome of his work might possibly be of the very greatest importance. They were now in a period when the science of meteorology in the southern hemisphere was being rapidly advanced. There had been a great development in Australia by the formation of a Federal Meteorological Service, New Zealand was going ahead, the different South African Colonies were, he hoped, soon to realise the importance of a general Meteorological System, and in the south of South America the greatest strides of all were being made. He considered that Colonel Rawson deserved cordial thanks for the great amount of labour he had expended on an extremely promising subject.

Colonel H. E. RAWSON, in reply, said that he greatly appreciated the President's encouraging remarks. He hoped there were others present who would take up the subject with more advantages than he had. He had difficulty in obtaining access to the proper books of reference. If they were to take the years 1884 and 1893 as those in which the changes in the belt's oscillations had occurred, they would find that even in the northern hemisphere important results would be obtained. He had carried the inquiry on to India, and these were found to be peculiar years there also. With regard to Mr. Bayard's question, he did not share the opinion of Mr. Russell on this point. Our charts still showed the permanent systems, which were never absent from within the belt for a very long period. In some of the charts they could see clearly that the action-centre had a real progressive movement from Australia up to South Africa and back again. In the early months it was moving from east to west, and with the change of season, when the winter was over in South Africa, it began to move from west to east, and to go back to the vicinity of Australia. In the records of Mauritius its course could be traced both ways by the effects upon the barometer. Besides the so-called "permanent" anticyclonic system there were apparently secondary systems travelling within the belt quite independently of the main system. The main system was generally much more permanent over a district, sometimes prevailing for 14 days, while the little travelling systems might only stay at longest a couple of days. At the extreme ends of its course the main system would be found over much the same locality for weeks together, as was the case with the Siberian system in winter. But the whole matter requires much fuller consideration than it has yet received.

Captain M. W. C. HEPWORTH, in a communication to the Secretary, wrote :—

"Much to my disappointment I was unable to be present to hear Colonel Rawson read his paper, of which I received an advance proof, and upon which I beg to offer a few remarks. I think with Colonel Rawson that probably the anticyclones of the great oceans have, in addition to a seasonal oscillation, a

movement that is cyclic ; but whether the earlier Pressure Charts he compares with those of a later date, in support of his theory, are based on a sufficient number of observations to be comparable, seems to me doubtful. It is true that the South-east Trades of the Atlantic, and, I may add, of the Pacific and Indian Oceans, are met with farther north of the equator in some years than they are in others ; but there is, I think, no evidence to show that the northern limit of these Trade winds is farther north, or farther south, during a number of years consecutively. There can be no doubt that variations in the meteorological conditions obtaining in South Africa are mainly the result of change in the track taken by cyclonic depressions in transit over that continent ; and that the track these wind systems follow depends upon the position of the high-pressure belt ; but the dominating factor, in my opinion, is the position of the South Atlantic anticyclone, the influence of the high pressure lying over the land being comparatively small. In regard to the monsoon influence referred to by Colonel Rawson as having been noticed at the Cape during the period 1896-1900, I have no recollection of a wind resembling a monsoon there during the six years 1878-1883, when I had good opportunities of observing and estimating the direction and force of the wind on the south and south-east coasts of South Africa. A North-west wind in Table Bay, and in the neighbourhood of the Cape, was usually associated with the passage eastward of a cyclonic or hemi-cyclonic wind system, and as a rule the wind increased to gale force in winter. Occasionally a steady North-west breeze was experienced, when the barometer stood at 30·0 in. or lower ; and was accompanied by rain, mist, or fog. Colonel Rawson says that 'As long ago as Maury's time, it was recognised that South-east winds blew out of the north side of the belt of calms,' etc. Recent investigation has shown that this time-honoured idea requires modification. The wind blows from southward and eastward across, and to the eastward and northward of the southern anticyclones of the oceans ; and its prevailing direction to the westward of the high-pressure area would be northerly (north-east to north-west) but for the interruption caused by the passage of depressions travelling eastward, and skirting the southern segment of the anticyclones.

"Referring to the connection Mr. Nevill pointed out, and Colonel Rawson has commented on, between the excessive rainfall in Natal of the seasons during the period 1892-1894, and the abnormal frequency of ice in the Southern oceans during the period 1901-1903, it seems probable that in consequence of a considerable increase in the activity of the polar currents in the latter period —currents which bring the ice from the Antarctic into lower latitudes—the temperature of the air flowing above them was lowered, and the energy of cyclonic depressions which bring to South Africa much of the rain increased, by coming in contact with this colder air ; the result being increased precipitation. In connection with certain anomalies in rainfall referred to in the paper, and with the differences alluded to between the rainfall of the eastern and that of the western sea-board, I would point out that the rainfall on the Atlantic side of South Africa is associated with equatorial winds circulating in front of depressions progressing eastward, pressure diminishing and temperature increasing. While the wind systems are passing over the arid land they part with much of their moisture, and take up little or none, so that when the system is approaching the eastern sea-board this equatorial wind is accompanied by a bright sky and genial weather. It then, however, becomes a sea-wind, bringing with it a fresh supply of moisture ; especially as it nears the coast, when an increasing amount of moisture is drawn from the humid atmosphere above the warm Agulhas current. The sky clouds over as the trough of the depression advances towards the sea and the air is near the point of saturation. After the trough of the depression has passed, and the wind has shifted to westward or

south-westward—cold winds drawn largely from high latitudes—the rain descends, and continues to fall as the barometer rises and temperature falls. Similar conditions obtain in Australia; the west coast has its rainfall with equatorial winds, falling mercury, and rising temperature; the east coast with polar winds, rising mercury, and falling temperature. I consider Colonel Rawson's paper a very valuable contribution."

Ships Struck by Lightning.

Ships remote from the land are seldom damaged by lightning, despite the fact that some of the most awe-inspiring displays of atmospheric electricity are frequently witnessed by those on board of them. Standing rigging, and even parts of the running gear, are now made of steel wire; and this substitute for the old-fashioned hemp serves the purpose of a lightning-conductor when the ship is not fitted with such an aid to safety. The electric current is conveyed down the wire rigging, and reaches the sea through the vessel's metal hull. Damage only occurs if the current be interrupted on its way to earth. In a comparatively large proportion of instances the fore-royal truck is struck by lightning; that of the main less frequently; and the mizzen least of the three. Very serious casualties under this head occurred to warships and merchant vessels in the days of wooden hulls and hempen rigging. In July 1802, as thirteen sail of the East India Company were trying to round the Cape in the vicinity of Algoa Bay, homeward bound, two of them, the *Britannia* and the *Bombay Castle*, were struck by lightning. The foremast of each was soon enveloped in flames, and the two masts had to be cut away in order to save the ships and their combustible cargoes. A heavy gale was blowing, the night was dark, and the other ships of the fleet, which were hove-to at the time, were witnesses of this thrilling incident.

Many vessels are now fitted with lightning-conductors of approved types, lest the wire rigging should fail to carry off the electric current. In May 1896, shortly after a severe thunderstorm accompanied by lightning and rain in 3° S., 87° E., the P. & O. steamship *Victoria*, Captain W. D. G. Worcester, R.N.R., had a sudden increase of deviation amounting to 6° in both the standard and the wheel-house compasses, and later on it was discovered that the lightning-conductor on the fore had fused. The ship must have been struck by lightning during the storm. At 10·55 on the night of December 29, 1907, in 35° 50′ N., 21° 20′ E., the P. & O. steamship *Britannia*, under the command of Captain S. Bareham, outward bound to Sydney, N.S.W., came under the influence of a heavy thunderstorm, accompanied by vivid lightning, a deluge of rain, and very large hailstones. A strong West-north-west breeze was blowing, the external air temperature in the shade was 60°, and the corrected and reduced barometer reading was 29·67 in. This weather continued till 5.30 on the morning of the 30th, in 35° 0′ N., 23° 20′ E., and it was discovered that during the night the fore lightning-conductor had been fused in places, and that the strands of the last 10 feet of it had been opened out. Neither the *Victoria* nor the *Britannia* was injured, and this immunity from injury was doubtless due to the presence of lightning-conductors.—*Monthly Meteorological Charts of the North Atlantic and Mediterranean*, June 1908.

RESEARCHES ON THE COMPOSITION OF AIR AT GREAT ALTITUDES, WITH SPECIAL REFERENCE TO ARGON AND ITS ALLIES.

By L. TEISSERENC DE BORT, F.R.Met.Soc.

The attention of men of science has long been directed to the question of the composition of air at various heights in the atmosphere, and from the time of the first employment of *ballons-sondes* by Hermite and Besançon, several attempts have been made to collect air from great heights by means of apparatus designed by M. Caillete, and one of these was successful. The quantity of air obtained was almost two litres, and it was analysed by M. Muntz, who found argon present in the normal proportion.

The existence of an isothermal layer in the atmosphere was discovered some years ago by our work with *ballons-sondes*, and has been demonstrated also in the region of the tropical Atlantic by the cruise of the *Otaria*, and under the Arctic circle by our Franco-Swedish expedition. The idea suggested itself to some people that this phenomenon of the stoppage of the diminution of temperature might be accounted for by some distinct difference in the composition of the air at high altitudes. Although I did not myself share this view, and had suggested a dynamical explanation of the isothermal layer, it seemed to me to be none the less interesting to investigate the composition of the upper air. My explanation was based upon the absence of vertical movements accompanied by adiabatic expansion in the isothermal layer, and thus tended to represent the portion of the atmosphere as having an individuality of its own, and not being mixed up by the vertical movements of cyclones and anticyclones, which tend to make the composition of air uniform by constant agitation in the lower and middle layer of the atmosphere. Thus if there is any difference in the composition of air with altitude, it should be accentuated between the isothermal layer and the portion of the atmosphere on which that layer rests.

As the *ballons-sondes* now in use are much smaller than Hermite and Besançon's aerophile, which was an expensive structure of gold-beater's skin, it was necessary to utilise very small vessels for securing the samples of air from a great height. I accordingly set to work to devise a vessel which should confine the air with absolute security, dispense with stop-cocks, [the automatic closing of which is difficult on account of the very low temperature of the high atmosphere,] and which should enclose the sample of air at a perfectly definite height. Electricity was the agent employed. The collecting vessel was a glass tube with a finely drawn-out end, which was sealed after a very perfect vacuum had been made inside. When the tip of the capillary tube was broken at the desired height the air was expected to enter readily, and fill the tube, so that it only remained to fuse the capillary tip in order to secure the sample. The tube is opened by the tip being broken off by the fall of a little hammer, released by an electric contact, and it is sealed by another contact allowing the current from a small accumulator to raise to

red heat a platinum wire wound round the capillary tube, by which means heat is produced sufficient to melt the glass. Both contacts can be made either by the barometer at a pressure previously arranged, or by the clock-work of the meteorograph, and the whole operation is so conducted that no impurity can possibly affect the air in the tube, the apparatus being hung at such a distance below the balloon that there can be no trace of hydrogen in the air.

The apparatus, as first made on a very small scale, secured several little tubes of air in July 1907. I supplied several similar pieces of apparatus to the *Otaria* for use on the Atlantic; but the presence of salt in the sea air seems to have affected the contacts and they did not act properly

I pass over the various practical difficulties which presented themselves, and which have not yet been completely overcome. The very narrow limits of size and weight within which one had to work made the arrangements somewhat difficult, for it was necessary to use a very light accumulator and a very light glass receiver, which had also to be surrounded by a covering sufficiently strong and well hung to obviate the risk of breakage when it came to the ground.

The quantity of air collected was too small to permit of an ordinary chemical analysis, and I accordingly decided to confine myself to spectrum analysis, paying special attention to argon, neon, and helium. I have been confirmed in this decision by Sir William Ramsay, to whom I had the opportunity of submitting this matter in London in January 1908.

I have proceeded by two different methods: one, by absorbing all the elements of the air except helium and neon by means of carbon; the other by first separating the argon.

The result of the first experiment has proved the presence of argon in all the samples of air taken between 8000 and 14,000 metres (5 to 8 miles) as one would expect. Helium, distinguished by its yellow line in the spectrum, has been detected in most of the specimens, but the highest of all, that taken at 14,000 metres, showed no trace of it. Neon was clearly discernible in every case. The attempts to disclose krypton have not as yet given any result, but the experiments on this gas are not sufficiently numerous to permit of forming an opinion on the subject.

So far there has been no question of quantitative analysis, the volumes of helium and neon being so infinitesimal that it will be necessary to increase considerably the quantities of air collected, or to carry the technique of the operations still nearer to perfection before a quantitative result can be arrived at.—*Paris, June* 16, 1908.

PRIZE COMPETITION FOR TEACHERS.

WITH the view of encouraging the teaching in schools of facts regarding weather and climate, the Council of the Royal Meteorological Society invited elementary teachers and others to send in for competition essays on weather or climate, for which prizes of £5, £3, and £2 respectively were to be awarded.

The requirements were that an original sketch of a Nature Study lesson on weather or climate (not exceeding 1500 words) should be sent in, together with a brief summary of five other lessons to cover the whole subject of weather and climate.

The number of essays sent in was 180.

The list of awards was given in the last number of the *Quarterly Journal*, pp. 153-154.

The essays by Mr. W. C. Upshall and Miss A. B. Phillips, who obtained the first and second prize respectively, are printed herewith. The essays were illustrated by diagrams and drawings of instruments, but these are not reproduced. The Society does not hold itself responsible for the statements made in the essays.

WEATHER OBSERVATION IN AN ELEMENTARY SCHOOL.

BY W. C. UPSHALL, BROUGHTON, STOCKBRIDGE, HAMPSHIRE.

For some years the writer has included weather observation as a part of the Elementary Science teaching in the Upper Standards—V., VI., and VII.—of a small village boys' school. In the schoolmaster's garden is a small grass plot on which stands a screen of the Stevenson pattern, and containing a maximum thermometer, a minimum thermometer, and dry and wet bulb thermometers. On the edge of the grass plot is placed a rain gauge. A home-made barometer is mounted on the school wall, making up all the necessary instruments for observing and recording weather observation.

At 9 a.m. each morning six boys are allowed to record the readings of the different instruments in a note-book kept for the purpose, and which is made out each month as follows:—

SPECIMEN FROM PAGE SHOWING ONE DAY'S READINGS.

January 7, 1908

Dry Bulb of Hygrometer	48°·5	
Wet Bulb of Hygrometer	48°	
Maximum Temperature	51°	
Minimum Temperature	43°	
Amount of Cloud—0 to 10	10 Ni	
Rainfall in Inches	·88	
Barometer 29·35 corrected	29·25	51° F.
Remarks ⌒ ≡ stormy. ◍ at night . .		W.

Full instructions for observing are given in *Hints to Meteorological Observers*, by W. Marriott, F.R.Met.Soc., 1s. 6d.

At the end of each week the boys graph the readings on squared paper, and at the end of month the totals and averages are found.

General Lesson on Forecasting Weather.

Note.—It is not intended that the whole of the following should be included in one lesson, there being enough subject-matter to occupy several lessons.

I. *Weather Forecast for the Day.*

(*a*) Draw attention to the general weather forecast for the day in the daily paper. Reference will very likely be made to a disturbance somewhere in the Atlantic. Produce a chart showing storm tracks, and it will be seen that the British Isles lie right on the great highway of storms which can be traced across the Atlantic, and following, or in close proximity to, the course of the Gulf Stream. Note that the storms do not keep exactly the same track, or otherwise the same countries would always come under the influence of the relatively same part of succeeding storms.

(*b*) A simple illustration of a storm may be found in the whirlwinds of dust seen in the country at different periods of the year. Such a phenomenon has often been observed by the boys at the school from which this is sent. These volumes of dust whirl around and sweep forward up the hill. It will now be an easy matter to show how atmospheric disturbances may be set up by the unequal heating of different layers or portions of the earth's atmosphere.

The land and sea breezes occurring in the summer-time should also be observed and made a note of in connection with the same.

II. *A Cyclone.*

(*a*) In recording weather observations the boys will have noticed that the barometer reads highest in fine weather and falls as the weather becomes stormy. It should now be explained that every morning at eight o'clock messages are sent to the Meteorological Office in London from scores of places throughout the kingdom, telling the height of the barometer and the direction and strength of the wind, along with other particulars. The height of the barometer is marked down for each place on a blank map, and then lines are drawn through all places where the heights of the barometer are equal. These lines are called "isobars," and when so drawn always show either a number of concentric circles or a spiral.

Two charts illustrating these should here be shown to the pupils and explained.

When the barometer reads lowest on the inside we have what is known as a cyclone system, and when highest in the centre an anti-cyclone.

The wind whirls towards the centre in a cyclone, rushing in from all sides to fill up the place of the ascending warm air.

(*b*) Some day should be chosen when the weather forecast predicts an atmospheric disturbance. The pupils should be allowed to go outside

at various times—of course opportunely—chosen by the teachers, and note the atmospheric conditions, *e.g.* kinds of clouds, direction of wind, strength of wind, rain, barometric height. All of these should then be arranged by the teacher in proper sequence, so that the correct conclusions may be drawn.

The following conditions and sequence of events may commonly occur:—

A fine bright morning with a clear sky. To the west and south may perhaps be seen a faint haze. Perhaps in comparing the direction of the wind with the previous day it will have been found to have shifted from North or North-west to West and South. When the wind shifts in this direction it is said to "back." The pupils should make a sketch thus, showing circular movement of direction of wind. Streaks of clouds—Cirrus or Mare's Tail—may be seen, and these are followed by denser streaks, which gradually merge into a mackerel sky. As the wind changed from uncertain gusts to a stormy gale, the clouds varied from Cirro-Cumulus to Cumulus and Nimbus, while the rain increased from a drizzle to a steady downpour. By this time perhaps the wind would be blowing a hurricane, while the clouds drove across the sky furiously.

During this the height of the barometer should be noted every half-hour, and the alteration graphed on squared paper.

At some period there would be a lull in the storm and the graph of the barometer at this time stands lowest. This is called the "eye of the storm." Later on in the day the wind again increases, clouds cover the sky, and the rain falls heavily. The wind will now be found blowing from the East, North, or even perhaps North-west. On noticing the barometer we shall find a steady rise, which should be graphed as before.

(*c*) The teacher should now draw a diagram of what has been observed, the class copying it in their note-books.

Very often a storm such as has been described is followed by "secondary depressions," or smaller storms shorter in duration, but of no less violence.

In connection with the foregoing the amount of rainfall occurring during the gale should be observed and recorded.[1]

It should be noted that the front part of a cyclone is always very damp and warm; the rear cool and dry. To observe this readings of the hygrometer and thermometer should have been taken and graphed on squared paper. The lines showing readings of dry and wet bulb would be closer together at front of storm than at the rear.

III. *An Anticyclone.*

(*a*) Just as in the case of the cyclone, an opportune time should be selected for the lesson, and this can be chosen from the forecast given in the daily paper. Let this be read out to the class by one of its number. It will be necessary to extend the observations over several days, noting the readings of barometer, hygrometer, direction of wind, clouds, and temperature. All these to be carefully graphed.

[1] On more than one occasion the rain has been observed to be coloured, and then the boys have examined drops under the microscope. A small quantity can be evaporated and the sediment examined in the same way.

Having thus made the necessary preliminary observations the lesson on the anticyclone can be proceeded with.

(*b*) 1. A chart illustrating the barometric readings over that portion affected by an anticyclone should here be shown. Notice that the "isobars" are circular or nearly so, and that the highest reading of the barometer is towards the centre.

2. The winds circle in the opposite direction to that of a cyclone, being accompanied with blue sky, and pleasant freshness of the atmosphere. In winter we have brisk frosty weather, and in summer misty mornings followed by fine bright days.

3. Point out that in the cyclone the air pours in towards the centre and goes upwards, afterwards to spread out and descend down the centres of the anticyclones.

The Hygrometer.

Measuring the amount of water vapour in the atmosphere. Two Lessons.

I. *Absorption of Water by Solids and Liquids.*

Experiment 1.—Take lumps of chalk, sugar, etc., placing in a little water coloured with red ink. Weigh these before and after to show the amount of water absorbed in each case.

Experiment 2.—Take two beakers of the same size and height. Fill one with water to a certain measured height from the bottom. Weigh beaker first, and then beaker and water.

Do the same with the other beaker, using sulphuric acid instead of water.

Put both on one side for a few days and then examine. Weigh both again, and it will be found that the sulphuric acid has increased both in volume and weight. The liquid sulphuric acid presumably has absorbed some substance.

II. *Proportion of Moisture in the Air.*

An ordinary large jam-bottle—about 200 c.cm. capacity—is fitted with a cork in which are inserted two pieces of bent glass tubing. Two pieces of india-rubber tubing are fixed in the end of the bent glass tubing, one rubber tube being allowed to extend to an empty beaker placed below the level of the bottom of the bottle, so that when the experiment starts the water can be siphoned from the latter to the former.

In the glass tube, which is 10 ins. long and $\frac{1}{2}$ in. in diameter, is placed some calcium chloride—a hygroscopic substance.

The tube containing the calcium chloride is carefully weighed, replaced, and the water allowed to run from the aspirator, afterwards measuring the volume of water drawn off. This will represent the volume of air which has passed over the calcium chloride in the tube.

Now weigh the tube, finding its increase in mass.

All this experiment can be performed by the boys themselves.

Record the results thus—

Weights of tube and $CaCl_2$ before exp.	32·50 grms.
„ „ „ after „	33·65 „
Increase . .	1·15 „

Vol. of H_2O in bottle and therefore vol. of air, 200 c.cm.

III. *Experiment with a Dry and Wet Bulb.*

(*a*) Two unmounted thermometers are mounted on a retort stand. The left-hand bulb is covered with a piece of muslin which dips into a vessel containing water.

As soon as the muslin is thoroughly damp examine readings of the bulbs. Let the observation be repeated at different intervals during the day and on successive days, graphing the results on squared paper.

(*b*) Explain that the lower reading of the wet bulb is due to evaporation. In changing from the liquid form to a vapour the molecular state of the water is changed. Heat is the force which lessens the force of cohesion between the molecules of water, allowing it to become vapour, and this heat is taken from the mercury in the wet bulb.

THE BAROMETER.

Outline of Lesson. Two Lessons.

I. *Pressure of the Atmosphere.*

Experiment 1.—The sucker cannot be pulled off easily, because the air is pressing on the top of it, but not on the lower side.

Experiment 2.—The paper does not fall off the tumbler although the glass is full of water. This is owing to pressure of air on the paper.

Experiment 3.—The funnel has a thin sheet of india-rubber tied over the top. When the air is sucked out of the funnel the india-rubber presses inward in the form of a curve.

Experiment 4.—Get an air-pump and hand-glass. Allow several pupils in turn to put one hand on the glass while the air is being exhausted. Hand cannot be removed. This shows clearly that air has weight.

II. *Torricelli's Experiment.*

(*a*) Take a barometer tube about 34 inches long and fill it with mercury. Place the thumb over the open end and invert the tube, removing it to a cup of mercury.

A column of mercury now remains in the tube about 30 inches in height. Note that 30 ins. = 762 millimetres.

(*b*) Experiment to show that mercury stands at same level when the tube is inclined :—

When the tube is in vertical position the mercury stands at the height of 30 ins.

On inclining the tube the mercury still stands at the same level.

(*c*) Experiment to show that pressure of a column of mercury is 15 lbs. to sq. inch :—

Suppose the tube to have an area of 1 sq. inch in transverse section. Then the mercury balanced by the atmosphere consists of 30 cubic inches.

Now mass of 1 cu. inch of mercury = $\frac{1}{2}$ lb. nearly.

$\therefore$ „ 30 „ „ = 15 lbs.

III. *Construction of a Simple Barometer.*

Procure a barometer tube about 34 inches long; a piece of rubber tubing about 9 inches long and which will fit the barometer tube; a piece of glass tubing which will also fit into the rubber tubing.

Next get a smoothly planed piece of pine wood about 4 ft. by 6½ inches, and on this rule two red ink lines 32 inches apart. Carefully rule out a scale of inches and tenths on a piece of drawing-paper, gumming it on the board. A scale of millimetres may be placed on the other side, leaving just room enough for the barometer tube. Note 27·4 ins. = 696 mm.

In order to fill the tube fix the rubber tubing on the open end of the barometer tube and place a small funnel in the other end of the rubber tubing. Gently pour in the mercury until it fills the barometer tube and nearly three-fourths of the rubber. Now take out the funnel and put the short piece of glass tubing in its place.

It is now ready to place in position on the board, to which it is secured by clips. This must be done with great care, or otherwise air will get into the vacuum at top.

The clip holding the glass tube at the open end must be made to unscrew so as to adjust the level of the mercury at *g* each time a reading is taken.[1]

Crook's Vernier Ruler, 2s. 6d.—Harling, London—will enable the observer to read hundredths of an inch.

A piece of cotton wool in tube above the open end keeps out the dust.

IV. *How to measure Heights above Sea-Level.*

(*a*) Weight of atmosphere varies with height above sea-level.

Experiment with Spouting-jar.—Show that the pressure of a column of water varies with the height of the column.

The same follows with a column of air.

For every 1000 feet we ascend the mercury falls 1 inch; approximately, on the other hand, in descending a coal-mine the mercury rises the lower we go—1000 ft. in descending, mercury rises 1 inch.

(*b*) Weight of atmosphere varies according to quantity of vapour contained.

Experiment.—Boil a flask of water and note that the vapour ascends. Why does it ascend?—lighter than air.

Vapour is lighter than air.

Note that evaporation is always more or less going on from the surfaces of pools, streams, and seas.

Moist damp air is light; dry air is heavy.

The Thermometer.

It is here taken for granted that lessons have been given to the pupils on the thermometer while in a lower Standard.

[1] Such a one has been made and used by the writer for some years.

I. *Graduating the Thermometer.*

(*a*) *The Freezing Point.*—Place some pieces of ice in a beaker and notice the reading of the thermometer when placed in it. If the beaker be warmed so as to melt the ice the thermometer reads the same so long as any ice remains unmelted.

Use both a Fahrenheit and a Centigrade thermometer in this experiment.

"Freezing point of water is the melting point of ice."

Explain that the heat used up to melt the ice, or, in scientific words, "to alter the molecular constitution of the solid ice," is not recorded and is known as "latent."

Freezing point marked 32° on Fahrenheit thermometer.
" " " 0° " Centigrade thermometer.

Take a mixture of salt and ice and notice that the melting ice then shows a lower temperature.

Tell the story that when Fahrenheit constructed his thermometer he supposed that 0° F. was the lowest degree of cold which was obtainable.

(*b*) *The Boiling Point.*—Take a test tube as in the accompanying diagram. When the water boils note the temperature, making use of both a Fahrenheit and also a Centigrade thermometer.

Note that the mercury is stationary at boiling point.

Explain that the heat used up to turn the water into steam, or, in scientific words, "to alter the molecular constitution of the liquid water," is not recorded and is known as "latent."

Boiling point marked 212°, *i.e.* 32° + 180°, on Fahrenheit.
" " " 100° on Centigrade.

II. *To compare the Readings on Fahrenheit and Centigrade Thermometers.*

(*a*) By diagram show that

100 divisions Centigrade = 180 divisions Fahrenheit.
5 " " = 9 " "

(*b*) Maximum and minimum Thermometers.—These to be shown and the uses explained—and how to read them.

(*c*) Exercise in changing degrees Fahrenheit into Centigrade. Let each boy draw a graph. Practise in reading from graph, *e.g.*

0° C. = 32° F. 30° C. = 86° F. 60° C. = 140° F.

Show that in turning F. degrees into C. we must first subtract 32°.

Also when changing C. into F. add 32°.

Give exercises to be worked and each pupil check on graph.

THE RAIN GAUGE.

Principle of the Rain Gauge.

(*a*) Take an ordinary jar or tin fitted with a funnel so as to nearly resemble a rain gauge. Now pour water into the jar through the funnel to height of ½ inch. Next procure a long narrow glass jar, pouring the water from the ordinary jar into this one.

Take a strip of paper the height of the water in the long glass and divide it into 50 equal parts. Paste it on the narrow glass jar and it becomes the measuring-glass.

We are now able to measure so small a quantity as $\frac{1}{100}$ of an inch or ·01 inch.

(*b*) By measurement we find that

1 gallon of water = 277·274 cubic inches

i.e. $l \times b \times h$ = 277·274 „ „

Suppose the area of a funnel to be 2 square feet.

$\therefore \quad 2 \times h = 277{\cdot}274$ cubic inches

$(2 \times 144) \quad h = 277$

$\therefore \quad h = 1$ nearly.

Thus 1 inch of rain is equivalent to 1 gallon of water spread over 2 square feet.

(*c*) Show how to graphically record the rainfall collected day by day.

NATURE STUDY.

By Miss A. B. PHILLIPS, 34 Blythe Hill, Catford.

Scheme of Six Nature Study Lessons on Weather and Climate, suitable for children of an Average Age of 10 years in an L.C.C. Elementary School.

1. An Autumn Morning: formation of Dew, Mist, and Fog.
   A Winter Morning: appearance and formation of Frost.
2. Clouds: their formation, appearance, and movements.
   Rain, Thunder, and Lightning.
   A Rainbow.
   Hail and Snow.
3. The Rain Gauge. The Barometer. The Thermometer.
4. The Weathercock: the Wind and its effect upon the Weather.
5. English Climate contrasted with that of Tropical and Frigid lands.
6. Natural conditions affecting Climate.

Note.—This subject could not be covered satisfactorily *with children* in six lessons; each of the above with children's observations and questions would make two or three lessons.

Lesson I.

An Autumn Morning. Time, 1 hour. *Class* 4. Average age 10 years.

Some of you came across the park this morning coming to school, and the shortest cut is across the grass plot. Did you notice your boots after this? Yes, they were quite wet and all the bright polish gone—*the grass was wet.* Did you notice dampness anywhere else? Yes, some *plants near the ground* had drops of water, like bright beads, glistening upon them; yet you know it had not rained during the night.

What was this water? It was *Dew. Whence come,* and *how formed?* This question you cannot answer, you were not up or out early enough to know. Well, have you seen this same condition at any other time of the day? *In the evening.* Mother has often said, "Come off the grass,

dear, it is getting damp," and yet you know then certainly that no rain has fallen. How, then, has it come?

Here is a glass of cold water which Mary has just brought in; she will tell you that she found it standing in a basin surrounded by ice, where it has been for the last half-hour. Now watch and tell me what is happening. Yes, the glass is getting misty, and now you can see drops of water on it. Do you think they have come from the water in the glass? No, they are on the outside, and glass would not allow it to get through, for it is, for all practical purposes, non-porous; beside which it stood all the previous half-hour, and there was no sign of damp until it had been some seconds in the warm room.

Now we have learnt before that there is *always water vapour in the air*, sometimes more, sometimes less, but always some, but *I must tell you* what you do not yet know, that *warm air will hold more water vapour than cold air.*

Now the air in this room is warm and charged with water vapour. If it is cooled at all (which it *is* by the presence of the ice-cold water and glass), some of this vapour is given up in the form of water (*condensed vapour*) as you see it on the glass.

This is what has happened in the field. The ground, which has been warm all day, and has been warming the air immediately above it, gets cool very quickly, much more so than the air. Every blade of grass and leaf, etc., grows cool, and the warm air touching it is chilled by the contact and gives up part of its water vapour in the form of these drops.

Formation of Mist and Fog.

When we were practising for the races some month or two back, do you remember that you had to leave off in the middle of the races, because the atmosphere became quite thick so that we could not see, and one of you said it was *a white fog.* Well let us see if that had anything to do with the water vapour of the air. Can you guess why it is so often misty and foggy here at C——, especially in and near the park? Well it is partly because there is so much water. The streams that add so much to the beauty of the place are partly the cause of the discomfort.

All day the sun is warming the water and the land (you know how hot the ground is if you sit down on the grass at midday, and the water is similarly warm).

The air lying immediately over the earth and water is being warmed, *not by the heat of the sun's rays streaming through it*, but by radiation from the land and water.

As evening comes on and the sun goes down, neither the water nor the land receive any more heat. They now begin gradually to cool, and as the land gives up its heat much more rapidly than the water, the air in contact with the land gets much cooler than that over the water, and when these two bodies of air meet, the cooler chills the warmer, and the same phenomenon occurs (the same thing happens) as in the case of the dew, only *the condensation is more gradual and not so thorough*; and the water vapour becomes visible, and remains as a mist or fog closely over the earth.

Now you have learnt how mist and fog are formed (by the meeting of air of one temperature with *some* body of a lower temperature).

People from the country are often puzzled by the blackness of London fogs—this is due to the smoke and dust of the city. Town fogs are *usually* thicker and darker than country or sea fogs.

Perhaps, now, you can see why, when *the sun comes out*, if it shines for any length of time, *the mist or fog disappears*—it is because the air is again receiving warmth from the earth, and that is *changing* the same condensed vapour *back into its true vapour* condition, in which *it is invisible.*

A Frosty Morning.

I now want one of you to tell me what the garden looked like this morning, when you got up and raised the blind.

The grass, thickly covered with white, looking in the distance like a thin coating of snow—the plants edged with white and glistening—bare trees encrusted with the same—the air bright and keen.

What is this which we call *frost* [Hoar-frost] ? *Where does it come from ?*

It is formed in very much the same way as dew, only before the water has time to form on the leaf, as in dew, it has frozen and *ice is deposited instead of water.*

What becomes of it ? It disappears when the sun comes to it ; yes, it is dissipated by the warmth and evaporated.

Summary of chief facts taught.

Dew is formed after sunset.
Dew is formed by the condensation of water vapour from the air.
It is found only near the ground.
Water vapour is always present in the air.
Warm air will hold more water vapour than colder air.
Hoar-frost is frozen vapour.

Summary of Lessons.

Lesson II.

Clouds :—

(*a*) Masses of vapour floating in the sky.

(*b*) Formed by constant evaporation—vapour lighter than air—rises —higher it goes colder it becomes—cold air condenses—becomes visible and is driven in various directions by the wind.

(*c*) Sudden fall in temperature causes particles to run together and fall *as raindrops.*

If they pass through colder layers of air in descent, the drops are frozen and drop *as hail.*

If frozen before descent commences they fall *as snow.*

Thunder and Lightning. — When two cloud-masses meet *Electricity* is *generated* and discharged, and *the report* of the discharge is *heard as thunder.*

Some materials are better conductors than others—means used to prevent danger—conditions to be avoided during a thunder-storm.

Rainbow.—Prismatic colours—due to refraction—raindrops as prisms—position—back to the sun.

Reason of rounded shape is the roundness of the raindrops—try looking through angular prism.

Lesson III.

Rain-gauge.—Show one, or make a model. Can be seen at Greenwich.

Note.—Funnel, Can, Measure.

Barometer.—Same method followed in this case. Have a barometer. Pressure of air. Scale for measuring variations.

Thermometer.—As above. Warmth of air, marked by scale. Children should keep daily records of the last two if possible. If they attend the science school, they would be more interested after making the instrument in a simple form.

Lesson IV.

The Weather-cock:—

(*a*) Children have been noticing it daily and *keeping record.* State more clearly for the class what they have observed. Smoke will often tell the direction of the wind.

(*b*) *Direction* in which the *school lies.* Children notice and tell later the direction of their own house.

(*c*) *Method of naming winds,* by the direction *from* which it blows.

(*d*) This will often tell us the *character* of the *wind;* according to the land or sea, heat or cold of its passage.

The weather-chart, kept by class, can be used here.

Lesson V.

English Climate contrasted:—

(*a*) *Zones* of climate. Torrid. Temperate. Frigid. Stories and known *facts concerning these, e.g.*—

1. Desert travellers. Sailors going through Red Sea. Missionaries of India, etc.
2. Life here at home.
3. Stories of Franklin, Davis, and other Arctic explorers. Life of Laplanders and Esquimaux.

(*b*) *Direction of the sun's rays* (briefly and simply).

Lesson VI.

Natural Conditions affecting Climate:—

The Latitude will not always satisfactorily account for climate. Other conditions modify—

(*a*) Height above sea-level.

(*b*) Nearness to ocean or sea.

(*c*) Sheltered or exposed condition of country; direction of mountain ranges intercepting winds.

(*d*) Character of the prevailing winds.

(*e*) Where near sea, influence of warm or cold currents.

In connection with known Geography, this lesson will be more interesting.

Brilliant Sky Glows, June 30 and July 1, 1908.

Brilliant sky glows were observed in many different parts of the United Kingdom on the night of June 30 and on several succeeding nights, the phenomenon being apparently at its maximum intensity on the night of July 1. The whole of the northern part of the sky, from the horizon to an altitude of about 45°, and extending to the west, was suffused with a reddish hue, the colour varying from a pink to an Indian red, whilst to the eastward of north the colour was distinctly a pale green. No flickering or scintillation was observed on the reddened sky, nor was there any tendency to the formation of the streamers or luminous arch characteristic of aurora. Cirro-stratus clouds near the horizon were tinged with the same colour as the surrounding sky. A special feature in connection with the phenomenon was the prolongation of twilight, extending almost to the following daybreak, and from the experience cited by many observers in various parts of Great Britain the light at midnight was sufficient to allow of fairly small print being read without any aid from artificial light.—*Nature*, July 9, 1908.

Mr. J. W. PHILLIPS of Haverfordwest, in a letter dated July 2, said :—

"On the last two evenings (June 30 to July 1) I have observed here the most unusual prolongation of twilight, in fact it did not become dark or anything approaching it on either of the dates named.

"On the 30th a police constable on night duty told me he was able at 12.30 to distinguish people more than 100 yards away, and at 1 A.M. it was as light as dawn, the sky then having peculiar greenish and yellowish tinges. Last night at 10.15 P.M. it was quite easy to read a newspaper in the open air, and at 12 and even 1 A.M. I could read my watch easily. The light extended from north-north-west by north to north-north-east, and had not the appearance of aurora, the amount of cloud being about 5 (ci.) and almost calm. Many persons mistook the time and thought their watches had stopped.

"Upon inquiry at the Atlantic Relay Office, I find that no earth-currents have been recorded of late, and a message was received from Valencia that they had observed the lengthened daylight, but had noticed no earth-currents."

Prof. BOHUSLAV BRAUNER of the Bohemian University, Prague, in a letter to *Nature* of July 9, said :—"The peculiar light phenomenon at midnight on June 30 which was seen, according to the papers, on the northern part of the sky at Copenhagen, Königsberg, Berlin, Vienna, Biala, and other places, was also observed by me at Prague. At 1.30 A.M. on July 1, I saw, in the direction north-east and north-north-east, a peculiar strong orange-yellow light over the horizon, the colour of which was more orange in its lower parts and more yellow in its higher parts. Its upper limit was lying twenty to thirty degrees above the horizon. The whole sky was cloudless. Other people saw it here at 11 P.M. on June 30. It is reported that magnetic disturbances were experienced on the telegraph lines, but I saw no trace of the characteristic of auroral bands or columns. I may be allowed to add that, according to Arrhenius, this time of the year corresponds to the minimum auroral display (activity). Interesting is the fact that a high barometric maximum was lying in the north, and that we had winds from that direction for a whole week."

PROCEEDINGS AT THE MEETINGS OF THE SOCIETY.

March 11, 1908.

Ordinary Meeting.

Dr. HUGH ROBERT MILL, President, in the Chair.

JOHN EWART TROUNCE BARBARY, 49 Dolcoath Road, Camborne;
EDMOND HUBERT BRANDT, 15 Lennox Gardens, S.W.;
ELIJAH HOWARTH, F.R.A.S., Weston Park Museum, Sheffield;
ARTHUR EDWARD JONES, 2 St. Mark's Square, Regent's Park, N.W.;
WILLIAM RICHARDSON NASH, Carke-in-Cartmel, Lancashire;
ARTHUR A. RAMBAUT, D.Sc., F.R.S., Radcliffe Observatory, Oxford; and
GEORGE PENN SIMKINS, P.H.D., Dacca, Bengal,
were balloted for, and elected Fellows of the Society.

THE PRESIDENT, Dr. H. R. MILL, said that he had much pleasure in making a statement with respect to the competition initiated by the Society with the object of ascertaining the extent to which meteorology was understood and taught in Elementary schools in this country. The Society had offered three prizes for the three best essays by teachers and others on "Climate and Weather," the essays to be in the form of a lesson, and accompanied by a syllabus for a complete course of lessons. The essays received had been more numerous than was anticipated, no less than 180 having been sent in. These had been considered by the Local Scientific Societies' Committee, and Mr. Bayard had kindly undertaken the task of going through them and sorting them. Mr. Marriott had then read them, and carried the classification farther, and, after a final scrutiny by Mr. Bayard, the result was as follows:—The first prize of £5 is awarded to Mr. W. C. Upshall, of Broughton, Stockbridge; the second prize of £3 to Miss A. B. Phillips, 34 Blythe Hill, Catford; and the third prize of £1 to Mr. Albert Stevenson, St. Paul's School, Sunderland. In addition to these prizes, it has been decided to award two extra prizes of £1 each to Mr. John Young, of Barrock by Wick, and Mr. Henry Collar, of Lavender Hill School, Clapham Junction, whose essays were very close to the first three. Two prizes have also been awarded to pupil teachers: £1 to Mr. Arnold B. Tinn, 28 Macaulay Road, Birtley, Huddersfield, and 10s. to Miss Daisy E. James, Church House, Wokingham. A considerable number of the essays had been sent in by children, and prizes have been awarded to Stewart Dobson, 70 St. John's Park, Blackheath, and Lily Francis, Black Notley School, Braintree. The result of the competition showed that the study of the weather had been handled intelligently in many schools, and it was hoped, that having thus received these various suggestions from teachers and taught, the Society would be able to found upon them some definite suggestions for the improvement of teaching this subject in Elementary schools.

THE PRESIDENT said, that the formal business of the evening being completed, he had the extremely pleasant duty of introducing to them the lecturer, though there was no one among the eminent meteorologists of the world who required less to be introduced to the Society than Dr. Hellmann. Dr. Hellmann was not only an Honorary Member, but he had been present on a comparatively recent occasion, the Jubilee celebration of the Society, when he had officially represented the German meteorologists in conveying their congratulations to the Society. All those who were present at that time would look forward with pleasure to the subject of Dr. Hellmann's lecture. The present meeting

was graced by the presence of representatives of the German Embassy and of the German Consulate-General, whom he welcomed with pleasure. He had also received a considerable number of apologies from those who were unavoidably prevented from being present. Among these he regretted in particular the absence of the President of the Royal Geographical Society, Sir George T. Goldie, who wrote, he was sorry not to be able to honour the President of the Berlin Geographical Society by coming to his lecture, but although he did not wish to charge the Meteorological Society with any undue responsibility, it was the state of the weather that rendered it impossible for him to come out. Dr. Hellmann had made a very special study of the early history of meteorology, on which he was the leading authority, and it was a great honour to the Society that he should have been willing to come on this occasion, despite great personal inconvenience, and he had come across the North Sea through the heart of one of their best developed cyclones. He, the President, was sure that all present would accord to Dr. Hellmann the heartiest of welcomes.

Dr. G. HELLMANN then delivered a lecture on "THE DAWN OF METEOROLOGY." [This Lecture will be printed in the next number of the *Quarterly Journal.*]

Dr. W. N. SHAW said that it was his privilege to propose a vote of thanks to Dr. Hellmann for his extremely able and interesting lecture. He felt more or less at home in proposing this vote of thanks, because Dr. Hellmann, as a Director of the Prussian Meteorological Institute, was a colleague of his as Director of a Meteorological Office. He was not betraying any great secret in saying, that the Director of an Institute was a peculiar person in this respect: he went to his work late, and made up for it by leaving early. He also had no special duties, but got the credit for all the work done by his assistants. Dr. Hellmann, as a Director, was in a favourable position for absenting himself from his office, but he, Dr. Shaw, was certain that Dr. Hellmann shared with him the feeling, that somehow or other the office got on better if the Director were regular in his attendance. It might be just a matter of taking an interest in the work of this or that department, but the work would be much improved. It was therefore the greater sacrifice for Dr. Hellmann to absent himself, and they would all unite in a vote of thanks to Dr. Hellmann for his kindness in coming that night. The lecture was a profoundly interesting one, as it dealt with a part of the subject seldom otherwise touched upon, also the manner in which it was presented would ensure that every one would carry away some idea of the story of the dawn of meteorology. Moreover, this story had been told in a language which was not the language of the lecturer. He, Dr. Shaw, had tried to make himself understood in other languages, and could heartily congratulate Dr. Hellmann on his success in overcoming the difficulties of a foreign tongue. Dr. Hellmann had discussed the Dawn of Meteorology. There was a very great effort being made in this country towards the progress of meteorology. He hoped that, although the dawn of meteorology extended back to a very long time, even before Babylonia, Dr. Hellmann might be spared to come back and give them another lecture on the "Noon of Meteorology." He had great pleasure in proposing a vote of thanks to Dr. Hellmann.

Mr. RICHARD BENTLEY said that—though difficult to glean in a field already traversed, and to-night so happily by Dr. Shaw—he rose very cordially to support the resolution conveying the thanks of the Society to their distinguished guest. When the first tidings of Dr. Hellmann's intention to visit this country had become known among the Fellows it had afforded them the liveliest satisfaction to welcome him again in their midst. To-night, however, to those fortunate in being present that pleasure had been increased tenfold after the interesting discourse they had just listened to, and it was also felt to be a great compliment to the Society that a meteorologist of the high position and

international eminence of Dr. Hellmann should come especially for this particular occasion all the way from Berlin (and that too at an inclement season of the year) to give the fruits of his labours to others in this country interested in the science. In recent years, owing to the great improvement in the manufacture of automatic and other scientific instruments, and the synchronous records of observations over wide areas rendered possible by the development of telegraphy, the progress of meteorology on modern lines had been very considerable. From this very cause, however, there was some danger of the historic side of this science being overlooked, and so they were still more indebted to Dr. Hellmann for helping to fill this void by the exceedingly valuable and complete survey which he had given to-night of the genesis of meteorology; indeed, within the brief compass of a single hour he had been successful in summarising the labours and investigations of more than twenty years. His audience had not only profited by the knowledge of so expert an authority on all pertaining to weather, but also by the researches of a distinguished scholar, and they were glad to have such a mass of valuable information enrolled in the pages of the Society's Journal. He (Mr. Bentley) had therefore great pleasure, on behalf of all present, in seconding the resolution.

THE PRESIDENT said that it was almost superfluous for him to put to the meeting the vote of thanks which had been so well proposed and seconded, and so enthusiastically received, but as formality sometimes made it necessary to do superfluous things, he had, in their name, to express to Dr. Hellmann their very deep appreciation not only of the excellent lecture, but also of his kindness in coming so far to give them the benefit of his great learning on the evening which was always expected to be the most attractive meeting of the year. These lectures were important because they seemed to show, not only to the Fellows, but the outside world, that the Royal Meteorological Society was carrying on work which, important as it was in the present, had its root in the distant past; that it dealt with principles which, besides embodying the results of modern science, had in many cases been foreshadowed by the ancients. He did not think that they had ever before succeeded so well in placing before the public this idea of the antiquity and the dignity of meteorology as to-night when listening to this address.

Dr. C. HELLMANN, replying, said that he thanked them all, and especially his colleagues, Dr. Shaw and Mr. Bentley, for their very kind welcome. He hoped that some day an English meteorologist would come and give a lecture to Berlin on the state of meteorology in England.

THE PRESIDENT remarked that a copy of the facsimile of Merle's Journal was on the table, and he invited any one desirous of inspecting this interesting volume to do so.

April 15, 1908.

Ordinary Meeting.

Dr. HUGH ROBERT MILL, President, in the Chair.

CHARLES BROWETT, Ryton-on-Dunsmore, Coventry; and
ALEXANDER MACMORAN, K.C., 3 Temple Gardens, Temple, E.C.;
were balloted for, and elected Fellows of the Society.

Geheimrath Prof. Dr. RICHARD ASSMANN, Director of the Königliche Preussisches Aeronautisches Observatorium, Lindenberg, Kreis-Beeskon;
KIGOO NAKAMURA, Director of the Imperial Meteorological Observatory, Tokio, Japan; and

Prof. ABBOTT LAWRENCE ROTCH, M.A., B.Sc., Director of the Blue Hill Meteorological Observatory, Hyde Park, Mass., U.S.A.,
were balloted for, and elected Honorary Members of the Society.

THE PRESIDENT, Dr. H. R. MILL, said that it was with great regret he was again obliged to preface his remarks with a reference to the death of one of the leading British meteorologists—on this occasion that of Sir John Eliot. Although Sir John Eliot had completed his great Climatological Atlas of India, embodying the fruits of his labours as head of the Meteorological Service of India, he died before the volume of text accompanying it was ready for publication. He had been a member of the Council of the Society, and, though his residence abroad had prevented frequent visits to the Society, his work had made him familiar to all the Fellows.

The President mentioned that, in connection with the Bill for improving Agricultural Education now before Parliament, he had taken the opportunity of following the example of his predecessor, Mr. R. Bentley, and had written to the Right Hon. Jesse Collings, M.P., who had charge of the Bill in the House of Commons, pointing out the desirability of including meteorology or weather study in the schedule of subjects. Mr. Collings had replied most cordially accepting the suggestion, and expressing the hope that the Bill would become law.

The President then referred to the forthcoming Franco-British Exhibition at Shepherd's Bush, and said that the Society was exhibiting in the Science Section. Amongst the exhibits it was hoped that there would be a complete Climatological Station at work in the grounds. There was no difficulty in finding the station, but to show it at work would require the services of observers to take the observations punctually at 9 A.M. and 9 P.M. He trusted that several Fellows would come forward willing to take these, for, say, a fortnight at a time, to share the work with those who had already promised. Observations would have to go on from May 15 till about the end of October.

The following communications were read :—

1. "REPORT ON THE PHENOLOGICAL OBSERVATIONS FOR 1907." By EDWARD MAWLEY, F.R.Met.Soc., V.M.H. [This Report will be printed in the next number of the *Quarterly Journal.*]

2. "THE ANTICYCLONIC BELT OF THE SOUTHERN HEMISPHERE." By Colonel H. E. RAWSON, C.B., F.R.Met.Soc. (p. 165).

CORRESPONDENCE AND NOTES.

Meteorology and Agriculture.

At the Royal Agricultural Society's Show held at Newcastle-on-Tyne from June 30 to July 4, a very interesting and attractive exhibit was arranged by the Royal Meteorological Society in the Agricultural Education and Forestry Exhibition. The exhibit included a large number of diagrams relating to rainfall, temperature, sunshine, the influence of weather on crops, health, etc., and also a collection of photographs illustrating meteorological phenomena. Various patterns of self-recording and other meteorological instruments were also shown ; and as most of these were at work, the visitors could see at once the changes which were taking place in the weather.

The methods adopted for obtaining information on the meteorological condi-

tions prevailing in the upper regions of the atmosphere were fully illustrated. A large kite with a meteorograph and also a ballon-sonde carrying a small meteorograph were suspended from the roof of the building. Diagrams exhibiting in a graphic manner some of the results obtained from Mr. Dines's observations were inspected with much interest, as these showed that the temperature decreases pretty uniformly up to a height of about 7 miles, above which there is practically little or no further change in temperature.

In a railed-off enclosure outside the Exhibition building, a fully-equipped Climatological Station was arranged with the various instruments in position, and at this station an address was given each day by Mr. W. Marriott on "Meteorology in Relation to Agriculture."

When the Prince and Princess of Wales visited the Show on July 1, they spent some time in the Royal Meteorological Society's Exhibit, and were greatly interested in the account of the upper-air investigations, and in examining some of the instruments and photographs.

Practical Open-Air Demonstration to Children.

As the result of conversation with some teachers attending the Royal Agricultural Society's Show at Newcastle-on-Tyne, Mr. Marriott promised to give an address to a number of school-children when he visited Keswick a week later.

By the kindness of Mr. A. Mitchell Dawson, arrangements were made by which the senior boys and girls, with their teachers, from several schools in the neighbourhood were able to be present in his beautiful garden on Friday morning, July 10. Mr. Marriott showed and described the various meteorological instruments used by Mr. Dawson in making his observations, and pointed out many of the results obtained from them. Under such favourable conditions, practical references were made to temperature, wind, clouds, rainfall, etc., which the children could easily follow.

Representatives were present from Brigham School, St. John's School, Crosthwaite School, and Braithwaite School, Keswick.

The Brontometer.

The late Mr. G. J. Symons, F.R.S., was from a boy greatly interested in thunderstorms, and he was for a long time engaged in devising an instrument to show the sequence of the various phenomena occurring during thunderstorms. He subsequently consulted MM. Richard Frères, of Paris, on the matter, and after deciding upon what the instrument was to do, and upon the scales required, he left the whole constructional details to them. The result was that in 1890 MM. Richard made for him an elaborate apparatus, which he called a "Brontometer," or Thunderstorm-measurer.

The following is Mr. Symons's description of the instrument:[1]—

"It is provided with endless paper, 12 inches wide, travelling under the various recording pens at the rate of 1·2 inch per minute, or 6 feet per hour. This is about 150 times faster than is usual in meteorological instruments, and enables the time of any phenomenon to be read off with certainty to a single second of time.

"The traces are made in ink by a series of seven Richard pens.

"The first pen is driven by the clock which feeds the paper, so that the time scale and the paper must go together. The pen usually produces a straight line, which serves as the base line for all measurements, but at 55 seconds after each minute the pen begins to go, at an angle of about 45°, one-tenth of an inch to the left, and at the sixtieth second it flies back to its original position.

[1] *Proceedings of the Royal Society*, **48**, p. 65 (1890).

"The second pen is driven by one of Richard's Anemo-cinemographs, a name which they have given to a pattern of anemometer not yet known in England. The external portion has some resemblance to the ordinary wind-mill governor, but it differs from it in that the plates are curved, not flat; they are made of aluminium, and are so light that they have little momentum, and thus have a great advantage over cups, which run on for many seconds after the wind force has decreased or ceased. The fans make one revolution for each metre of wind that passes, and send an electric current to the brontometer, where it acts on an electro-magnet, and tends to draw this (2nd) pen towards the left; but a train of clockwork is constantly tending to draw the pen to the right, the joint result being that the pen continuously shows, not the total motion (as is the case with most anemometers), but the actual velocity almost second by second. It does this certainly with an error of less than five seconds, for the fans will stop dead in less than that time, and the clockwork train will bring the pen from indicating a velocity of 70 miles an hour to 20 miles an hour in three seconds, and down to a dead calm in seven seconds. The trace will thus resemble that of a pressure anemometer, but with a much more open scale than was ever before available.

"The third pen is actuated by a handle, and can be set at zero or at 1, 2, 3, or 4 spaces from it. The author's original idea was, partly by watching a storm-rain-gauge, and partly by estimation, to decide on the intensity of the rain and to indicate that intensity by moving the pen further and further from zero as the fall becomes heavier. Experience alone will show whether that is, or is not, superior to moving it one step for each $\frac{1}{100}$th of an inch of fallen rain, which can be done by making a Crosley rain-gauge send a current into the room where the brontometer is placed, and strike a bell there. In a heavy storm there will, however, be so much for the observer to do, that very probably count would be lost. It may, therefore, be necessary to make it act automatically.

"The fourth pen is actuated somewhat like a piano. On the occurrence of a flash of lightning, the observer presses a key, the pen travels slightly to the right, and flies back to zero. Referred to the automatic time-scale, this gives, to a second, the time at which the key was depressed.

"The fifth pen is similar, but, being intended to record the thunder, the observer will continue to hold down the key until the roll is inaudible. The time of the departure of this pen from zero will evidently be later than that for the lightning by the time-interval due to the distance of the flash, and possibly something may be learned from the accurate record of the duration of the thunder.

"The sixth pen is similar to the third, and is intended to record the time, duration, and intensity of hail.

"The seventh and last pen is devoted to an automatic record of atmospheric pressure. As the rapid motion of the paper, which is indispensable for studying the details of a thunderstorm, has enlarged the time-scale more than a hundredfold, it was imperative that the barometric scale should itself be greatly enlarged. But the range of the barometer in London is more than $2\frac{1}{2}$ inches, and no enlargement less than ten times the natural (mercurial) scale would be of any use; hence a breadth of 25 inches of paper would be necessary, unless some mode of shifting the indication could be devised.

"Several plans were tried, but finally a modification of Richard's statoscope has been adopted, which is so sensitive that it will indicate the opening or shutting of a door in any part of the house, gives a scale for 30 inches for each mercurial inch (*i.e.* about three times that of a glycerine barometer), and yet only requires 4 inches breadth of the brontometer paper. Without entering into

all the details of construction, it is desirable to explain the general principle, and its application. As it was essential that the apparatus should record accurately

THE BRONTOMETER.

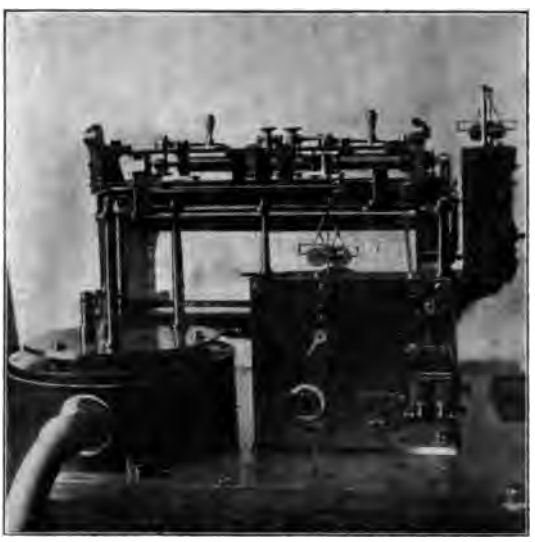

FIG. 1.—Front View.

FIG. 2.—Top View.

to 0·001 inch of mercurial barometric pressure, it was evident that friction had to be reduced to a minimum, and considerable motive power provided. This is done by placing in the base of the brontometer a galvanised iron chamber,

which contains about 3½ cubic feet of air; on the upper part are a series of elastic chambers, similar to the vacuum boxes of aneroid barometers, but much larger.

"When the instrument is to be put in action, these chambers are connected with the large air-chamber, and a tap is closed which shuts off communication with the external air. Any subsequent increase, or decrease, of atmospheric pressure will compress or allow to dilate the air in these chambers, and the motion of the elastic ones produces that of the recording pen.

"Obviously, any large change in the temperature of the confined air would vitiate the readings; but (1) the instrument is not required to give absolute, but merely differential, values; and (2) the influence of the changes of temperature is greatly reduced by the chamber being surrounded with 4 inches thick of non-conducting material, besides nearly 1 inch of wood outside of it. The change of temperature in a room, and during the short time that the statoscope will be worked without resetting to zero (*i.e.* without opening the tap), has not hitherto produced any measurable effect."

The Brontometer came into my possession about two years ago. As I have no facilities at my house at West Norwood for putting up the Anemo-cinemograph, no wind records are made on the instrument.

I use the third pen for hail, and the sixth pen for rain—that is, transposing the records from those mentioned by Mr. Symons.

Reproductions from photographs of the instrument are given on page 209.

Fig. 1 is a front view of the upper part, which is fixed to the top of the wooden case containing the large air-chamber. The clock which feeds the paper is on the right. The case containing the elastic chambers of the statoscope is on the left-hand side. The tubing connecting this with the air-chamber below is seen in the lower corner. The clockwork for the Anemo-cinemograph is to the right of the statoscope case. On the top of the instrument will be seen the handles for moving the hail and rain pens, and also the keys for the lightning and thunder pens.

Fig. 2 is a view of the top of the instrument. This shows the position of the various pens as they pass over the endless paper.

I have not had many opportunities of using the Brontometer, as I am often away at the critical time—and thunderstorms do not come on "to order," —but such records as have been obtained have been of great interest. The thunderstorm which occurred on June 4, 1908, was not only a very severe one, but it afforded almost exceptional opportunities for obtaining records on the Brontometer of the various phenomena accompanying the storm. The particulars of this thunderstorm are given in a separate note.—WM. MARRIOTT.

Brontometer Records at West Norwood, June 4, 1908.

As the thunderstorm on Thursday evening, June 4, at West Norwood was of such an intense character, I think it may be of interest to give some particulars about it.

The weather during the day had been very hot and close, the *maximum* temperature being as high as 84°·7. Thunder was heard in the afternoon from about 2.40 to 3.10. A fresh storm came on about half-past 5, when distant thunder was heard. This storm gradually developed, and was most intense between 6.10 and 6.40. It continued till 7.30. After an interval of about a quarter of an hour another storm came on at 7.44, and continued till 8.30.

As I arrived home soon after 5.30, I got the brontometer to work, and so was able to obtain a record of the various features of the storm.

Ninety-eight flashes of lightning were observed in 28 minutes between 6.11 and 6.39. No records of lightning were taken from 6.39 to 6.45 owing to a fresh supply of ink being required to be put into the pen, but 63

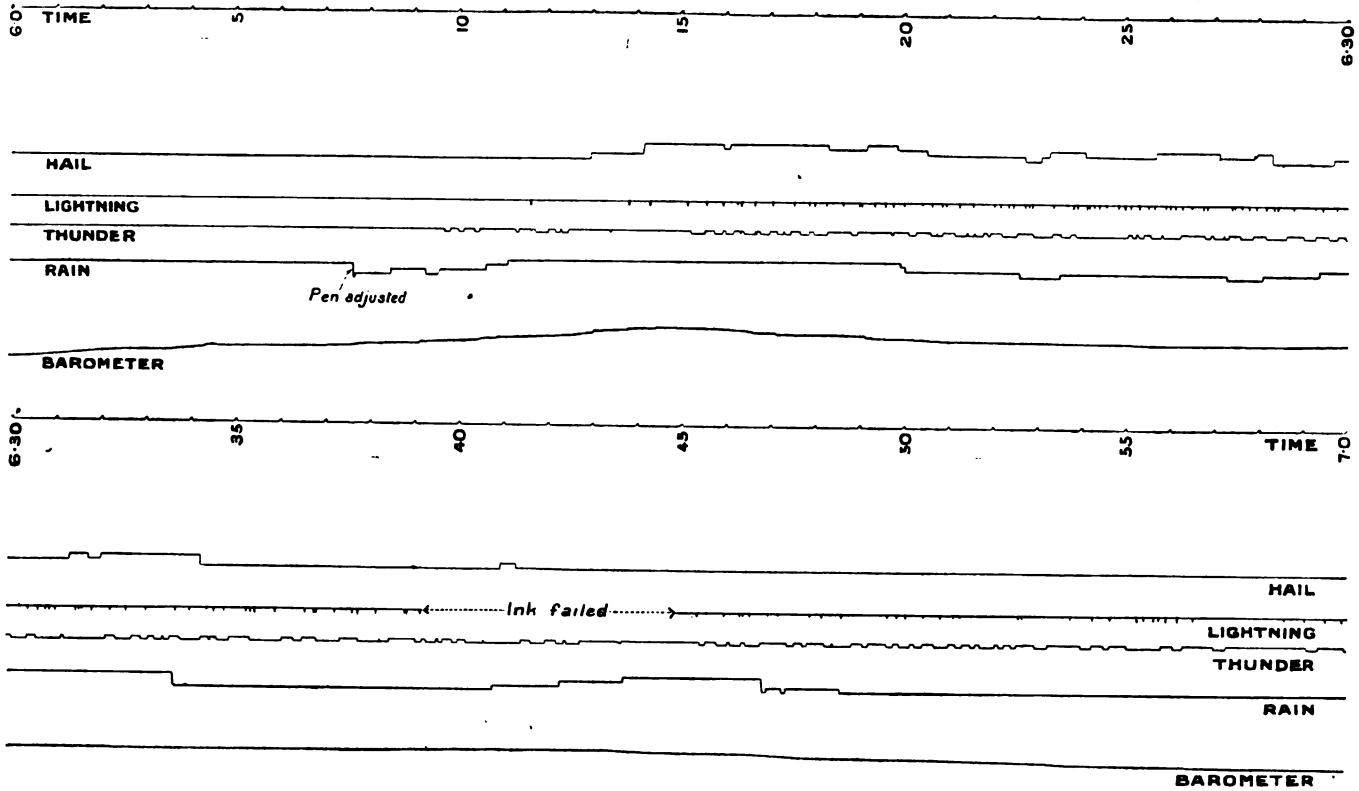

FIG. 3.—Brontometer Record at West Norwood, June 4, 1908.

flashes were observed between 6.45 and 7.30. Many of the flashes were of a brilliant character, and were mostly of the "flickering" or "repeating" type.

I recorded 123 peals of thunder between 6.10 and 7.30. There were probably considerably more, but it was most difficult to distinguish between the individual peals, as before one had ceased another or more would have been heard. The longest duration of the rumble of an individual peal of thunder was 70 seconds.

Rain fell from 6.8 to 6.33 and from 6.41 to 6.48. It was extremely heavy during most of this period. Hail also fell from 6.13 to 6.34, the hailstones being larger than, and somewhat similar in shape to, big-sized acid-drops. The intensity of the rain and hail may be gathered from the fact that 1·14 in. fell in 33 minutes.

The barometer began to rise at 5.58, and reached its highest point when the hail began. It then fell slightly from 6.20 to 6.30, after which there was a further slight rise till 6.43, when the pressure gradually slackened till 7.5, and then remained stationary.

A reproduction (on a reduced scale) of the record from 6.0 to 7.0 is given in Fig. 3 (p. 211).

During the last storm 39 flashes of lightning were observed and 39 peals of thunder were heard between 7.44 and 8.29. Rain commenced falling at 8, and continued till after 9 o'clock. The rainfall during this storm amounted to ·15 in.—Wm. Marriott.

The Thunderstorms of June 1 to 4, 1908, at Epsom.

The first week in June, marked by an excess of high day and night temperatures, was noteworthy for the occurrence of a series of severe thunderstorms. On June 1 a sharp thunder shower took place at 5.45 A.M., distant rolling thunder being heard to the west at 6 A.M. After a warm day, with a shade maximum of 79°·8, a thunderstorm came up from the south and south-west towards 8.40 P.M. Very vivid fork and sheet lightning in the south, south-west, and west, accompanied by loud rolling thunder, occurred between 8.50 and 9.30 P.M. At 9.30 P.M. a dust-storm of considerable extent arose, dust in whirls and eddies being carried up spirally to a considerable height. At 9.40 P.M., on the commencement of the rain, a wind-squall attaining gale force passed from south-west to north-east, causing in its track extensive damage to timber, large trees being rooted up and blown down in a direction towards east and north-east. The storm passed the zenith at 9.45 P.M., working away in a northerly direction. The final termination of the storm was not reached until near midnight. The rainfall from 9.40 to 10 P.M. was 0·70 in. The barographic trace marked a sharp jump in pressure from 29·80 in. to 29·87 in. shortly after 9.30 P.M. Further thunderstorms of a sporadic character took place at 1.30 and 2.45 A.M. on the 2nd.

On June 3, after a very warm day, the shade maximum attaining 80°, a brilliant display of sheet lightning was visible in the south, south-west, and west between 10 and 11.30 P.M., when a thunderstorm moved up rapidly from the south-west, prevailing to 12.45 A.M. on the 4th. On its original track this storm would have crossed the zenith, but its course was changed by the influence of the high ground of the North Downs, and it passed south-east. Rain amounting to 0·05 in. fell between 12.25 and 12.35 A.M. At 1.15 A.M. on the 4th a further heavy storm came up from the south-west and west, a magnificent display of fork lightning being the prevailing feature, flashes varying between six and ten per minute being of frequent occurrence and of dazzling brilliance. The accompanying thunder was of a marked booming

nature with a long roll; the storm was practically continuous till 3 A.M., remaining apparently stationary in the west and south-west for an hour and a quarter and then receding. No rain fell. A sharp drop in pressure occurred at 2 A.M. from 30·00 in. to 29·95 in. No reduction in temperature was exercised by the storm during the early morning hours of the 4th, the succeeding day being intensely hot, with a shade maximum of 83°·3. A cloudless sky prevailed till 2.30 P.M., when thunder clouds (cu-nim) came up from the north, accompanied by thick haze. From 4.15 to 5.30 P.M. distant thunder was heard in the east and south-east. At 5.45 P.M thunder clouds were visible in the north, north-east, and south-east, south-west, west, and north-west, a very heavy thunder-storm being noticed working up from north-west and west. Fork lightning accompanied by loud rolling thunder commenced at 6 P.M., the wind blowing in hot gusts from North and North-east. A very heavy fall of hail, lasting four minutes, took place at 6.15 P.M., the landscape being temporarily blotted out by the falling hail, and the ground covered as with a white sheet. The hailstones caused considerable noise in their descent and were of varied form and size, the majority egg-shaped (about equal to a blackbird's egg), others more or less square with ragged edges, whilst several pieces of ice with a rime coating were picked up. When split open the stones had a nucleus of clear ice; many were of considerable size owing to the agglomeration of several stones. Torrents of rain commenced on the cessation of the hail at 6.19 P.M., continuing till 7 P.M., extensive flooding taking place owing to the drains being choked; the roads leading off the Downs were converted into running torrents. The storm passed the zenith at 6.30 P.M. on a south-east course, vivid fork lightning and severe thunder being almost continuous. The end of the storm was reached at 7.30 P.M. Temperature at 6 P.M. was: Dry bulb 75°, wet 69°; and at 7.30 P.M., dry 65°, wet 64°. The barograph showed a sudden increase in pressure about 6.15 P.M., 29·87 in. to 29·92 in. The rainfall from 6.15 to 7 P.M. was 0·90 in. Towards 7.45 P.M. a second storm came up from the north and north-east, dense yellow gloom and a thick mist prevailing. A further display of vivid fork lightning and loud cracks of thunder lasted to 8.45 P.M., the storm passing in an easterly direction. The rainfall from 8 to 8.10 P.M. was 0·31 in.

A marked reduction in temperature was experienced in the rear of the storms, the exposed thermometer on the grass falling to 29°·8 on June 7.—SPENCER C. RUSSELL, *June* 10, 1908.

Lakeland Sayings about Weather.

The natives of Cumberland and Westmoreland have an extraordinary range of local expressions referring to the state of the weather, partly, perhaps, because the Lake District gets more than its share of rainfall, and numerous shades of meaning have from time to time arisen to meet the very variable conditions of the weather in that part of the country. A few samples are given below. It's "spittin' a laal bit," refers to a few drops which will probably soon be over. It "mizzles and rains" betokens a condition of things equivalent to a mild Scotch mist. It "hadders and rains," is equivalent to showers. "Nobbut a sup o' fell rain," purely local rain in the region of the fells is not considered a great evil. But when there is a "gert pash," a tremendous downpour is clearly meant. It is rather paradoxical to remark it's "fine an' wet," a reference to really heavy rain. By old-fashioned folk extremes are called "cruel het" and "cruel cauld." "Clashy Brough Hill weather" is almost proverbial, so often does a storm occur about Michaelmas, when this great fair of the North is held. "Glisy" applies to a day when the sun comes out in fitful gleams very brightly, and is next quickly overclouded—not a very favourable sign. "Eh, we're hevin' gran' growy weather," the Cumbrian

farmer exclaims with delight when gentle showers come on a warm day. "It's ter'ble hask wedder," is another localism. "Hask" means harsh, rough, penetrating, all rolled into one, and specially applies to the East wind, which is at its worst when Cross Fell has "t' Hellum" on—*i.e.* the Helm wind. Lightning is most frequently referred to as "fire"—*e.g.* "t' fire was summat awful." A fall of snow which appears likely to be followed by still worse weather is called a "feeding storm."—*Penrith Observer*, June 23, 1908.

The Rain-tree of Queensland.

Amongst the last parcel of produce received at the City office of the Queensland Government, 73 Basinghall Street, are some pods of the "rain-tree" (*Pithecolobium Samam*), an importation into the Colony from Peru. It is a valuable shade tree in tropical pastures. The name of "rain-tree" is given because so great is the volume of distillation of moisture that the ground is wet under its branches.

Relation between the Weather and the Flowering of Fruit-trees.

In a paper read before the Royal Statistical Society in January 1907, Mr. R. H. Hooker drew attention to the correlation of the weather and the crops, and pointed out that an examination of the meteorological statistics and of the returns of the produce of crops suggested that the yield was influenced not merely by the character of the weather during the later stages of growth, but also during seed-time. Some similar conclusions in regard to the flowering of fruit-trees have been arrived at by Mr. E. P. Sandsten, of the Wisconsin Agricultural Experiment Station (*Bulletin*, No. 137). He points out that the time of flowering in the spring of a given variety of fruits is dependent upon a number of causes or conditions, chief among them being, first, the number of positive temperature units received in the spring preparatory to flowering; second, the stage of development of the flower-buds as dependent upon the climatic conditions of the summer and autumn preceding the flowering; third, the fruiting of the trees, whether light or heavy, the year previous to flowering; fourth, the soil conditions, and the amount of plant food present in the soil; and fifth, the individual characteristics and state of health of the tree or plant. From the data given in the *Bulletin* it would appear that there is but little relationship between the time of flowering and the temperature in the spring up to the time of flowering, while there appears to be considerable evidence that the temperature and other climatic conditions during summer and autumn preceding flowering have much to do with the time of flowering.—*Journal of the Board of Agriculture*, March 1908.

Icebergs of the Southern Hemisphere.

On the *Monthly Meteorological Charts of the Indian Ocean* for April 1908, some particulars are given respecting icebergs in the southern hemisphere. It is stated that icebergs occur irregularly, and they vary very considerably in size and number. For years in succession icebergs, and occasionally field ice, will be seen by ships traversing the Southern Ocean southward of Cape Horn and the Cape of Good Hope. Afterwards a whole decade may elapse before similar conditions are experienced. During the first six years of the period selected for this discussion, 1885 to 1907, icebergs were scarce in all the Southern Ocean within the limits of navigation; but from the close of 1891 up to the latter months of 1895, there were numerous reports of icebergs and ice-islands in great numbers and of phenomenal magnitude. There was also much field and drift ice. Between 1896 and 1905, however, there were very few reports of ice of any kind over the Southern Ocean. In 1906 a considerable amount was met with near Cape Horn; and this appears to have drifted north-eastward as far as the meridian of Cape Leeuwin in some instances.

Southern icebergs are formed along the seaward edge of the Antarctic ice-cap; but whether they are broken off the water-borne extremities of glaciers protruding into the sea, as is the case with Arctic bergs, or whether they are simply wrenched from the ice-cap itself under the influence of seismic disturbances in the vicinity, remains yet to be proved. Once adrift from its place of origin an iceberg or an ice-island follows the path of least resistance, which coincides with the resultant of such forces as ocean-stream, drift-current, sub-surface current, and prevailing wind.

Icebergs have been seen in close proximity to the Cape of Good Hope in January and in August, and near Cape Leeuwin in January, but the northernmost ice ever met with in the Southern Ocean appears to have been that reported by the master of the barque *Dochra* on April 30, 1894, when in 26° 30′ S., 25° 40′ W. The vessel passed close to the remnant of an iceberg, which was 4 ft. high, 12 ft. long, and 4 ft. wide, under very favourable conditions for observations. The sea was smooth; the time was 10 a.m., and the weather was fine. Icebergs were also seen exceptionally far to the westward in comparatively low latitudes in 1893 and 1894. In June 1893, the s.s. *Milton* passed one in 45° S., 60° W.; and three days later the s.s. *Titania* sighted a berg apparently aground in 44° S., 59° E., which was 250 ft. high and 2 miles in length. Twelve months later H.M.S. *Garnet* passed an ice-island estimated to be 10 miles long, which similarly appeared to be aground, in 46° S., 61° W., about 330 miles north of the Falklands. These three instances show that it is unsafe to assume that the passage between the Falklands and the mainland is always free from ice.

In April 1892, the *Cromdale*, in 46° S., 36° W., was in the presence of innumerable bergs, one of which was 1000 ft. high as reported personally to the Meteorological Office by Captain Andrew on arrival in London. At daylight she was discovered to be standing into a horse-shoe shaped bay which had been hollowed out of one side of an ice-island of awe-inspiring magnitude. Vertical icy cliffs, over 300 ft. high, were on either side, and right ahead; and at least 50 peculiarly opaque bergs were adrift in this bay. Eventually Captain Andrew succeeded in beating out into open water without mishap. This peculiar form of berg is not by any means unique, and the fact should be remembered by seamen. In January 1893, for example, the ships *Wasdale* and *Stracathro* were in company in 47° S., 42° W. One day at sunrise they found themselves in an iceberg's horse-shoe shaped bay. It was 20 miles long, 4 miles across at the entrance, and increasing to a width of 20 miles in the middle area. Dampier, in his *Voyages*, has described just such an ice-island. Throughout the five months ended April 1855 there was probably the largest ice-island on record drifting about between 44° S., 28° W., and 40° S., 20° W. This danger was hook-shaped and had a height of 300 ft. Its longer shank stretched 60 miles without a break, and the shorter was 40 miles long. Between these promontories of ice was a bay 40 miles across. Three vessels became embayed, under the mistaken idea that they were running between two huge parallel ice-islands, and one of them was wrecked. The *Great Britain* coasted along a side of this danger for 50 miles. In June 1892, the *Duntrune*, going ten knots, collided with a large berg in 47° S., 38° W. Her bowsprit was broken short off, her foretopmast came down on deck, her bows were stove in, and the sea poured into the forecastle. At daybreak this berg was found to be 300 ft. high, and it stretched north-east and south-west from horizon to horizon. About the same date, in 54° S., 51° W., the *Wellington* collided with a berg, and was compelled to put into Rio Janeiro for the necessary repairs. Early in the month the *County of Edinburgh* passed numerous bergs in 45° S., 37° W., ranging from 200 ft. to 900 ft. in height; and, not far remote, the

Stanmore was encircled by bergs some of which were 5 miles long and flush with the water. Such low masses of ice are especially dangerous; as they can only be discerned by the breaking of the sea over them. In April 1893, in 49° S., 51° W. the *Brier Holme* was surrounded by bergs, some of which had an altitude of 500 ft. to 1000 ft.; and the *Charles Racine* sighted a berg, 50° S., 52° W., which was 1000 ft. high and "several miles in extent," thus confirming the report from the *Brier Holme*.

During June 1906, a number of very large bergs were seen in the vicinity of Cape Horn. Between 58° S., 58° W., and 58° S., 68° W., the *Monkbarns* sighted a tabular berg which was 200 ft. high and 5 miles long, and another 200 ft. by 3 miles long. The *Ascensione* reported one 600 ft. high and 6 miles long, and probably aground.

In May 1892, the *Strathdon*, Captain A. T. Wills, was surrounded by icebergs in 45° S., 25° W. They were of enormous size, and she narrowly escaped collision with one, during the prevailing fog, which was at least 1000 feet high. The only opening seemed scarcely wide enough for the barque to pass through, and her yards almost touched the ice on either hand as Captain Wills stood boldly out for the open water. Next day the vessel sailed 40 miles along one side of an ice-island which had an altitude of from 800 ft. to 1000 ft. In April 1895, the *Lowther Castle* was similarly surrounded by icebergs, one of which was 635 ft. high by sextant, in 45° S., 25° E., and she had very remarkable escapes from collision with one or other of these dangers during the ten days ice was in sight on her way east. About the same time the *Earnock* fell in with a berg in 46° S., 20° E., and for several days she sailed between long rows of icebergs. At one instant not fewer than 100 were in sight from the barque's deck; and altogether she must have passed over 900, some of which were 600 ft. high and 3 miles in length.

RECENT PUBLICATIONS.

About the Weather. By MARK W. HARRINGTON. New York, 1907. 8vo. xx + 246 pp.

This is one of Appleton's "Home Reading Books," and is consequently written in a very simple style. The author is a master of his subject, as he was for some years the head of the U.S. Signal Service. In the Preface he says: "In the theory of education, which above all aims to be practical, in selecting branches of instruction that are best fitted to be turned to account in life and experience, a study of the art of forecasting the weather must naturally hold a high place: and, indeed, in any system of education, few fields of scientific investigation offer more interesting and valuable results in teaching close and discriminating observation of nature, and in reasoning out and drawing logical conclusions from given premises, than does this study."

The following extract from the chapter on "General Storms, Cyclones, or Lows" will give an idea as to the style in which the book is written:—

"The most remarkable discovery in the modern study of the weather is the cyclone. By this word is meant, not necessarily a furious destructive storm, but only a circular mass of air—a flat, thin vortex, shaped like a wafer, and having a system of internal motions of its own. These motions may be so intense as to be very destructive, but nine times in ten the cyclone is a very gentle creature—in some cases so gentle, that though it passes over our heads, it requires close observation and delicate instruments to detect it. It is not

once in a hundred times that a cyclone does any damage to man, even when we count an occasional stroke of lightning. The word cyclone, however, is so frequently misunderstood that meteorologists generally use others, except when they write for their fellow students of the weather. They often call these masses of air general storms, because they are great disturbances of the atmosphere, and therefore are storms in a proper sense of the word, though not always in the popular sense. To avoid the misapprehension that the word storm creates, meteorologists often use the word 'low' as a substitute for 'cyclone' or 'general storm,' because it has no evil popular associations with it. And this word is appropriate, for it expresses the state of the barometer in a cyclone. Besides, this is the word used on the weather map to mark the centre of the cyclone.

"The cyclone appears on the map as an area of low pressure. Around the centre the isobars are closed up, enclosing an area or island of low pressure. The enclosing isobars are usually nearly circular, but sometimes oval or even irregularly elongated. When they are so elongated that a projection or trough extends towards the equator, they are likely to develop a series of local storms of great interest."

Climate. Considered Especially in Relation to Man. By ROBERT DE COURCY WARD, Assistant Professor of Climatology in Harvard University. With Illustrations. London: John Murray, 1908. 8vo. xv + 372 pp.

The author states that this work is based on lecture-notes which have been accumulating for the last ten years. It does not attempt to present any very new or original material, but it does aim to co-ordinate and set forth clearly and systematically the broader facts of climate in such a way that the general reader, although not trained "in the technicalities of the science," may find it easy to appreciate them. At the same time, the needs of the teacher and student have been kept constantly in mind, and the subject-matter has been arranged in such a way as seems best to adapt it for purposes of thorough study.

The general scope and purpose of the different sections in *Climate* are as follows. The Introduction is essentially a very condensed synopsis of the first six chapters of Hann's first volume, *Handbuch der Klimatologie*, with the addition of some other matter. Chapter I. gives a sketch of the classification of the zones. Chapters II. and III. give a brief summary of the general climatic types which result from the control of land and water, and of altitude, over the more important elements of climate. Chapters IV., V., and VI. are intended to give an outline of the climatic characteristics of the zones in a simple and vivid form, with the least possible use of tabular matter. For further general information on this subject, reference may be made to the world-charts of temperature, winds, cloudiness, rainfall, etc., given with greater or less completeness in the various text-books of meteorology and, very fully, in the *Atlas of Meteorology*. In Chapter VII. the attempt is made to give a survey of some of the relations between weather and climate and a few of the more important diseases. Little information on this subject is readily accessible to general readers. The life of man in the tropics, the temperate zones, and the polar zones is considered in Chapters VIII. to X. No attempt has been made by the author to discuss this subject in detail, but it has rather been his plan to pick out typical illustrations here and there, as suggestions. Many of the cases referred to will probably be familiar to teachers and students of geography, but the co-ordination of all the examples by climatic zones and by the natural climatic sub-divisions of these zones will, it is hoped, tend to give adequate emphasis to the climatic factor, which has hitherto been much

neglected. The final chapter, on changes of climate, deals with historic and periodic, and not with geologic, changes. The last phase of the subject has been fully discussed in many books, while the former, which are of more interest to most persons, have received much less attention. The question of the influence of forests on climate, which many readers may expect to find considered in this book, is omitted because it is adequately taken up in Hann's *Handbook*.

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THE DAWN OF METEOROLOGY.

BY DR. G. HELLMANN,

Professor of Meteorology at the University of Berlin, Director of the Royal Prussian Meteorological Institute, Honorary Member of the Royal Meteorological Society.

[A Lecture delivered before the Royal Meteorological Society, March 11, 1908.]

(Plate 3.)

FIRST of all I beg to return my best thanks to the President and Council of the Royal Meteorological Society for having been so kind as to invite me to deliver this evening a Lecture before the Society. Highly appreciating, as you know, your Society, the oldest one of the kind existing, I gladly accepted the invitation, and have chosen as the subject of my lecture a theme which has not yet been fully dealt with in this country.

I shall speak on the earliest evolution of meteorology, when our science was in its infancy; but before proceeding to do so, let me ask you to excuse any errors which I may commit in your tongue.

Meteorology as a science is young, but as a branch of knowledge very old, perhaps as old as mankind. Indeed, the beginnings of meteorology are to be found with the origin of human civilisation.

In those remote times, man living as hunter or agriculturist mostly in the open air was more influenced by and more depending on the weather than we are ourselves at present, and he was therefore forced to watch atmospheric phenomena. He did so, of course, not in order to study the atmosphere and to discover its laws, but to derive immediate advantages for himself. He was anxious to learn how to protect his house against the inclemency of the weather, how to foresee the best atmospheric conditions for his undertakings, or how to find out the most favourable climatic situations for his fields.

The experience of the more intelligent men in this respect was handed down, and at the same time augmented, from generation to generation, and formed very early an essential element in the knowledge of the people.

It was the popular weather-wisdom which is still living nowadays and will never die. This weather knowledge soon assumed the form of short proverbs, or rather absolute rules, because thus they were easily committed to memory. Although a good many of these early weather-rules were based on the real observation of natural signs, such as winds, clouds, and optical phenomena in the sky, yet many of them arose out of false combinations and conclusions, and were, moreover, mixed with superstitious ideas which then pervaded all human thoughts.

It would, therefore, be wrong to imagine that the rich store of weather-lore found in the Bible, especially in the Book of Job, in the poems of Homer and Hesiod, that is, in writings of the eighth century B.C., originated then in Palestine or Greece. On the contrary, the familiarity of the people with the sayings and rules concerning the weather, revealed to us by these writings, show clearly that they must be considered even then as a primeval stock of culture. Indeed, there is every reason to believe that the origin of a great deal even of the modern weather-lore can be traced to its Indo-Germanic source.

In two instances I have succeeded in proving the great age of modern weather-lore, and it seems to me deserving of notice that in both cases weather-superstition is concerned, for it is notorious that nothing has such strong roots in the mind of the people as superstition.

You know well that people attribute a good deal of prognostic signification to the so-called "twelve nights" (or "twelve days"), which formerly were counted from the beginning of the year, but later, under the influence of the Christian Church, from Christmas. People believe that the weather of these twelve nights (or days) corresponds with that of the twelve months of the following year—indeed, a rather simple forecast of long range if it were true! This superstition is met in the whole of European literature back to the fifteenth century, and still earlier in many MSS. Also the venerable Bede mentions it; and the Byzantine-Greek work on agriculture, called *Geoponica*, which was collected in the sixth century A.D., tells us that even Democritus, in the fifth century B.C., was familiar with it in pretty much the same form. On the other hand, we learn from the Sanskritists that the old Indian or Vedic texts reveal the same belief in the twelve nights as a symbol of the following twelve months. But this superstition not only spread westwards with the Indo-Germanic race, it migrated also eastwards to China, where on New-Year's Day a custom is still in use which is based on the same Indo-Germanic conception.

Another superstition concerning the weather leads us to old Babylonia.

Many European chapbooks of past centuries, and a little Swedish book, *Sibyllæ Prophetia*, which is sold to-day at fairs, contain forecasts of the weather and fertility of the whole year deduced from the thunder heard in each of the twelve months. These "signa tonitrui" can be followed up in MSS. till the Middle Ages, and goes back apparently to the rich literature of thunder-almanacs or brontologies, in the composition of which in the fourth and fifth centuries even Byzantine emperors have taken part. In a similar chapter of the already cited Greek book *Geoponica* this doctrine is attributed to Zoroaster. Though this may not be the real author, yet his name indicates its

Oriental origin. And, indeed, I found in the works of the Assyriologists—Sayce at Oxford and Lénormant in Paris—some translations of cuneiform tablets proving the Chaldaic origin of this superstition concerning thunder.

The state of meteorology in the old Babylonian culture, namely, three to one thousand years B.C., shows quite another character than it did in those primeval times in which the weather proverbs originated.

After having been formed into the beginnings of a learned profession by the priests, the atmospheric phenomena were brought by them into connection with the constellations of the heavenly bodies, and a complete system of consequences and combinations was established which gave rise to the Astro-Meteorology. It even formed an integral part of the Assyric-Babylonian religion.

Thanks to the memorable discovery by Sir Henry Rawlinson of the astrological cuneiform library of Assurbanipal, now preserved in the British Museum, and of which some parts have been deciphered quite recently by Mr. R. Campbell Thompson and Rev. Franz Xavier Kugler, S.J., we got for the first time a very interesting insight into the astro-meteorological system of old Mesopotamia, the existence of which system was often alluded to by the writers of antiquity, but which was never fuller explained.

The meteorological observations of the Chaldeans were apparently of a quite selective nature, referring above all to optical phenomena, especially to the halos. They distinguished clearly the small halo of 22° diameter, called "tarbasu," from the greater one of 45°, called "supuru." Besides, they paid much attention to clouds, winds, storms, and thunder. But a good many of these observations served more for a general prophecy of good and bad things, or omens, than for the forecast of the weather. All these predictions were addressed to the King, and contained at the end the authority, that is, the name of the astrologer, on whom they were based.

Let me give some examples:—

(Thompson, 98).—When a dark halo surrounds the moon, the month will bring rain or will gather clouds. When a halo surrounds the moon and Mars stands within it, there will be a destruction of cattle. Aharru will be diminished (it is evil for Aharru).

(Thompson, 248).—When a cloud grows dark in heaven, a wind will blow. From Nabu-ahi-iriba.

(Thompson, 253).—When it thunders in the day of the moon's disappearance, the crops will prosper and the market will be steady. From Aššaridu.

It seems to me interesting to point out that in the Vedic texts, especially in the commentary to the Samaveda, similar consequences are deduced from rare meteorological phenomena, but with this difference that here also the sacrifices prescribed for them are indicated. And you know that at Rome also all extraordinary natural phenomena were considered as *omina* and *portenta* which had to be expiated by the priests.

No meteorological theory has yet been discovered in the Babylonian tablets, of which, of course, only a small number has been preserved, and even a smaller number deciphered. But I was quite recently greatly

surprised to find that the Babylonians had the windrose of eight rhumbs, and used already the names of the four cardinal points to denominate the intermediate directions; whereas it was till now generally supposed that we owe to Charles the Great, or perhaps to his learned monk Alcuin, who came from Yorkshire, this progress of the combination of the four principal winds to denote all others. That was indeed a great advance, for it is well known that in the Greek and Roman periods each wind had its peculiar name, a practice still in use amongst the Italian mariners in the Mediterranean.

The Babylonians counted the four cardinal points in the order South, North, East, West (*šutu*, *iltanŭ*, *šadu*, *amurra*), and by combining them with the word and (*u*), they formed e.g. *šutu u šadu* = South-east, *iltanu u amurra* = North-west, and so on.

From the Babylonians to the Greeks is a far cry, but there is also great progress from a meteorological point of view. It seems that the Greeks were the first to make regular meteorological observations, some results of which are still preserved, and that their great capacity for pure science induced them to establish meteorological theories

My first statement is not only proved by Theophrastus, who quotes several men in Asia Minor and Greece making meteorological observations, but also by the interesting fact that since the time of Meton, namely, since the fifth century B.C., in the so-called *parapegmata* (παραπήγματα), a kind of peg almanac fixed on public columns, the general data of the weather resulting from observations were exhibited. And as these weather-almanacs differed from town to town, it clearly follows that they were based on individual observations made in each district.

Here is an example taken from the *parapegma* of Geminos, whose book, entitled *Introduction to the Phenomena*, is of special value for this question:—

August 31.—The shoulders of Virgo are rising. The winds called ἐτησίαι cease to blow.
September 5.—Rising of Arcturus. South wind, rain, and thunder.
September 12.—The weather will likely change.
September 14.—Mostly fine weather for seven days, thereafter easterly winds.

I am able to show to you some fragments of such a *parapegma* found recently at Miletus, and now preserved in the Museum at Berlin (Plate 3, Figs. 1 and 2).

In the holes you can see in the marble stone little wooden pegs were put in order to fix the beginning of the year and the days, which gave rise to the name *parapegma*, to be derived from the Greek verb παραπηγνύναι = to fix into.

It is not surprising that in these *parapegmata* the observations of the wind prevail over all others, for they were of practical use to navigation and easily made. Also, the origin of the winds has always been a favourite subject of speculation among the Greek philosophers. In the epoch of Homer winds were still conceived as absolute beings like gods, whereas Anaximander of Ionia, who lived in the fifth century B.C., is the first to give a scientific definition of the wind, which is still valid. He says: ἄνεμον εἶναι ῥύσιν ἀέρος, the wind is a flowing of air.

It is therefore quite natural that the Greeks even at this early period

FIG. 1.—Fragment of Parapegma.

FIG. 2.—Fragment of Parapegma.

Copyright Opinion

used wind-vanes, which represent the older meteorological instrument, and a most interesting example of it is preserved in the "Tower of Winds" at Athens. But I am inclined to believe that the principal purpose of

FIG. 3.

this architectural monument, which your Society has chosen by way of emblem, was not the observation of the direction of the wind. The tower stands on the market-place in the low town immediately at the foot of the high Acropolis, and is therefore too much sheltered (Fig. 3). It was, perhaps, rather a useful time-keeper for the people attending the

market, since it contained a clepsydra, or water-clock, which was moved by the water of a still existing fountain in the neighbourhood bearing the same name κλεψύδρα. I suppose, therefore, that the architect, Andronikos Kyrrhestes, mostly for reasons of architectural beauty and harmony, combined with this poor-looking clock a more magnificent octagonal tower with artistic emblems of the winds. I am confirmed in my opinion by the fact that, according to Theophrastus, the astronomers and meteorologists of Athens avoided making their observations in the town, but preferred to go for this purpose to the top of Hymettos, which hill lies quite outside the town in an open situation.

At the time of the construction of the tower, namely, in the first century B.C., a great many wind-vanes were already in use; for a contemporary Roman writer, Terentius Varro, tells us that in Roman villas they were constructed in such a manner as to show the direction of the vane on a windrose fixed to the ceiling of the room ("ut intus scire possis").

Notwithstanding the great use made of the wind-vane, it has always struck me as curious that no Greek or Roman word for it has been handed down to us.

Soon after these earliest qualitative observations of the weather and direction of the wind we find the first quantitative ones, that is to say, the measurement of rain, in the first century A.D. It was made in Palestine, where the great influence of rainfall on the crops must have been fully appreciated at an early date, and the results of which observations are preserved in the Mishnah, a collection of Jewish religious books apart from the Bible. It seems to me most interesting to state that the amount of rainfall then considered as normal for a good crop corresponds pretty closely with that deduced from the modern observations made by Mr. Thomas Chaplin at Jerusalem, whence it can be inferred that the climate of Palestine has not changed. You know that the French scientist Arago came to the same conclusion mainly by phenological arguments.

Many of my audience will perhaps be astonished when I state that we are indebted also to antiquity for the first idea of a most important modern meteorological instrument. For, as I well know, most scientists are still of the opinion that antiquity achieved nothing concerning physical instruments and experiments. But the more we become acquainted with the scientific and technical literature of the Greeks and Romans, which at present is often the subject of study of philologists in preference to the classical authors, the more we learn their many positive results in this respect.

There are two physicists of special interest to us in this connection, namely, Philo of Byzantium, who lived in the third century B.C., and Hero of Alexandria, whose century is not yet settled, but who certainly lived after Philo and the great mathematician Archimedes, both being quoted by him. In the writings of these two physicists we find the description of an apparatus which represents the primitive idea of the thermoscope.

Philo's description in his work *De ingeniis spiritualibus* (On Pressure Engines), the Greek original of which is lost, only an Arabian and a Latin translation being preserved, will be made intelligible by Fig. 4. He says:—

One takes a leaden globe of moderate size, the inside of which is empty and roomy. It must neither be too thin that it cannot easily burst, nor too heavy, but quite dry so that the experiment may succeed. Through an aperture in the top is passed a bent siphon reaching nearly to the bottom. The other end of this siphon is passed into a vessel filled with water, also reaching nearly to the bottom, so that water may the more easily flow out. *a* is the globe, *b* the siphon, and *g* the vessel. I assert, when the globe is placed in the sun and becomes warm some of the air inclosed in the tube will pass out. This will be seen, since the air flows out of the tube into the water, setting it in motion and producing air-bubbles, one after the other. If the globe is placed in the shadow or any other place where the sun does not penetrate, then the water will rise

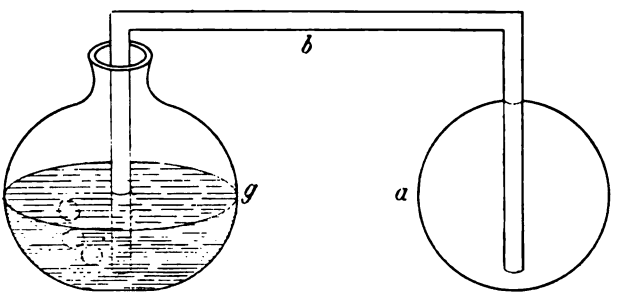


FIG. 4.

through the tube flowing into the globe. If the globe is again placed in the sun the water will return to the vessel, and *vice versa* . . . . The same effect is produced if one heats the globe with fire or pours hot water over it. . . .

Somewhat more complicated is the similar apparatus of Hero, to which he gives the name λιβάς, or drip (Fig. 5).

Now it happened that this book of Hero on pneumatics, which must have been widely distributed already in MS., was translated in the eighteen years between 1575 and 1592 no less than twice into Latin and three times into Italian. It was studied by Galileo, Porta, and Drebbel, and gave, about the year 1600, to all three men the idea of constructing a thermoscope, and to the last one also the impulse of making an experiment on the origin of the winds.

From this it appears there is an interesting connection between the science of two remote periods with an interval of time of more than 1800 years!

As I said before, the Greeks were also the first to start theories of meteorological phenomena. Indeed, since the time of the oldest philosophical school, that of Ionia, there are few Greek philosophers who were not interested in some branch of meteorology. This covered a wider field of research then than at present, embracing, besides meteorology in the modern sense, also a good deal of physical geography and astronomy, especially shooting-stars, meteors, and comets. The favourite meteorological subjects of speculation and research seem to have been the origin of the winds, the theory of the rain, including the regular inundation of the Nile, and the rainbow. A good many cosmological speculations were also put forward by the meteorologists which often

proved false, and, considered from a practical point of view, in all cases rather useless, whence in the period of Socrates meteorology itself came into disrepute. A new word was coined—μετεωρολέσχης instead of μετεωρόλογος—in order to designate a mean babbling about sublime things. Aristophanes' comedy, *The Clouds*, seems expressly composed for the derision of these theorisers.

But notwithstanding, meteorology made some real progress in time, and reached such perfection a century later that the system established by Aristotle remained for nearly two thousand years the standard text-book of our science. To be sure, considered from a modern point of view, Aristotle's meteorology was antiquated long ago, but if you imagine yourselves back in those old times you will agree with me that his treatise

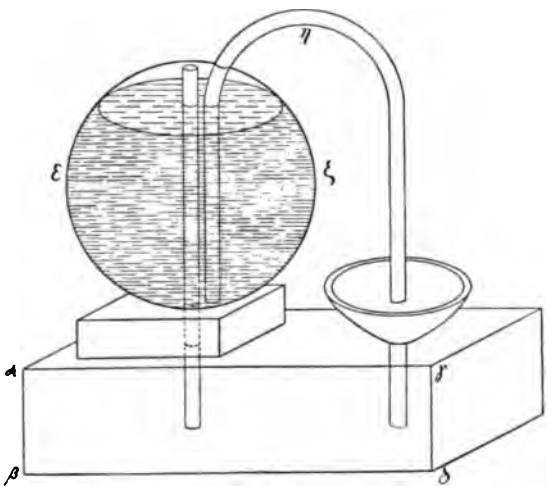


FIG. 5.

of meteorology—the earliest one existing—is an excellent piece of work, and well worthy of the greatest systematiser of all times.

I would go too far if I were to analyse here the merits and demerits of Aristotle's meteorology. It may be sufficient to say that his most distinguished successors, such as Theophrastus and Posidonius, have added but little to the perfection of his system, which, on the contrary, gave rise to innumerable commentaries and paraphrases. All text-books of meteorology issued on the Continent till the end of the seventeenth century are exclusively based on Aristotle, whereas, curiously enough, in England his influence was much less. If I except Duns Scotus, I do not know any British scholar who has written a commentary on the Meteorology of Aristotle, and even this one has quite recently been disputed. It is true, the number of treatises on meteorology published in Great Britain before 1700 is unusually small compared with that issued contemporaneously in Germany, Italy, and France, in Latin or the vernacular language.[1] Englishmen seem always to have been more

[1] Mr. G. J. Symons was of opinion that the earliest English book containing meteorological subjects was *The Kalender of Shepeherdes*, printed by Wynkyn de Worde in 1508. I can,

inclined to make actual observations of the weather than to theorise upon it and to write systematic treatises on meteorology.

Among the Romans meteorology made but little progress, like all other sciences of no immediate practical value. Pliny, Seneca, and Lucretius do not add any remarkable fact or theory to the knowledge of the Greeks, and probably the same can be said of the lost writings of Nigidius Figulus and Suetonius Tranquillus. From Virgil we learn some new weather-proverbs originating in Italy, and a writer on agriculture, Columella, who owned a large estate near Cadiz in Andalusia, has left behind a *Calendarium Rusticum*, or rural calendar, with many interesting weather-observations made in that district.

The extensive colonial possessions of the Romans were, of course, suitable for advancing the conceptions of climatological differences of the countries. As the great military expedition of Alexander the Great to Inner Asia and India had brought to the Greeks the first knowledge of the monsoon winds, so the Romans were the first to point out the difference between the continental and maritime climate. Minucius Felix, a Christian writer from Africa, living in the second century A.D., says, concerning the climate of Great Britain, "Britannia sole deficitur, sed circumfluentis maris tepore recreatur," that is, freely translated, "Britain has little sunshine, but a mild climate on account of the warm sea-water flowing round it."

The barbarous state of Europe after the fall of the Western Empire was not adapted to the furthering of science, which was barely kept alive within the Christian Church. Yet the pursuit of meteorology never wholly ceased; for the Fathers of the Church, writing commentaries on the work of the seven days, the so-called Hexaëmeron, often took occasion, when dealing with the first day of the Mosaic Creation, to insert long elaborations on the atmosphere and its phenomena.

At the very beginning of the Middle Ages the great encyclopedists, such as Isidorus Hispalensis in Spain, the Venerable Bede in Great Britain, and Rabanus Maurus in Germany, were the first to devote more attention to meteorological questions, the interest in which must have

however, state that the first English printer, William Caxton, had previously issued in 1481, a book dealing with meteorology. It is the *Myrrour of the Worlde*, "translated out of frensche into English by me simple person Wyllm Caxton," the French original being the *Image du Monde*, composed in the thirteenth century. The last chapters of the "second book" are entitled: Ayer and his nature; clouds and rain; frost and snow; hail and tempest; lightning and thunder; winds; fire and falling stars.

But a really systematic treatise on meteorology was not published in England until the year 1563. This bears the curious title: *A Goodly Gallerye with a most pleasaunt Prospect into the garden of naturall Contemplation, to behold the naturall causes of all kynde of Meteors, as wel fyery and ayery, as watry and earthly*, etc., and was written by William Fulke, "Doctor in Divinitie." This small book in octavo was reissued with varying titles in 1571, 1634, 1639, 1640, 1654, 1655, and 1670, and so passed through more editions than any other English meteorological book. The author deals with the subject in a more popular than scientific manner.

English students mostly made use of the meteorological treatise written in Latin by the Belgian professor Libertus Froidmont (Latinised Fromondus), *Meteorologicorum libri sex* (Antverpiae, 1627, 4°), of which three editions were issued in England, namely, Oxford 1639, London 1656, and London 1670.

Other treatises on meteorology published prior to 1700 are the posthumous work of Edward Brerewood, *De Meteoris* (Oxford, 1631; third edition, 1637); *Natures Secrets, or the admirable and wonderfull history of the generation of Meteors . . .* by Thomas Willsford (London, 1658 and 1665); and a small *Treatise on Meteorology* by the Rev. T. Robinson (London, 1696).

been considerable in England, for in the tenth century an extract of Bede's writings, concerning astronomy and meteorology, was made for the uninitiated in the Anglo-Saxon language, which is perhaps the earliest treatise on science written in a popular form. It contains chapters on the winds, rain, hail, snow, and thunder.

A general revival of studies took place at the end of the twelfth century, when the writings of Aristotle, among which was his Meteorology, came to the knowledge of the Western students by Latin translations made in Spain from the Arabian ones, not from the Greek originals. The imposing meteorological system of the great Stagirite again exercised a great influence on the writings of the scholars and on the teaching in the recently established universities, where, under the title "Meteora," regular courses and even exercises in meteorology were held. Albertus Magnus at Cologne wrote at this time his great meteorological works (*De Meteoris*, libri iv., and *De Passionibus Aeris*), paraphrasing chiefly those of Aristotle, but adding also the opinions of other authorities and his own remarks; and at the same time, or somewhat later, Vincent de Beauvais in France, Thomas de Cantimpré in Belgium, Ristoro d'Arezzo in Italy, Bartholomew Anglicus (or de Glanvilla) in England, incorporated the Aristotelian ideas in their encyclopedic works all bearing the general title, *On the Nature of Things* (*De Natura Rerum*).

But the firm and absolute adherence to the doctrines of the master, Aristotle, the denying of all that could not be found in his writings, rendered the scholastic meteorology so noxious to any real progress that it came into conflict with all new ideas. Notwithstanding, these forced their way by and by, and the beginnings of the modern experimental science are to be found just at that epoch when scholasticism had reached its highest point, namely, in the thirteenth century.

It is not yet definitely settled where the new experimental science took its origin—most likely contemporaneously in France and in England, where the two friends Pierre de Maricourt (Petrus Peregrinus) and Roger Bacon can be considered as the first great representatives of the new aims.

The former, a French nobleman and military engineer, is the author of the famous treatise on the magnet, and made many optical experiments like his English friend; and although both have not dealt with meteorology properly speaking—except the rainbow—yet their general influence must have been great on our science also. Roger Bacon's energetic opposing of the experiment to the argument—"argumentum non sufficit, sed experientia," he says in his *Opus Majus*—conduced naturally to the observing of atmospheric phenomena instead of only interpreting the writings of the ancients.

Thus the new aims advanced meteorological observations also, for which the ground was well prepared. As I have just shown, such observations were made in antiquity and never had wholly ceased, despite frequent and long interruptions. For the custom of the Roman historians to note in their annals the more important atmospheric phenomena, especially those necessitating sacrifices, was handed down to the chroniclers of the Middle Ages, whose chronicles became richer and richer in entries of the weather, till at the end of the thirteenth century these records are so replete with remarks on the weather that the character of the seasons could be traced back.

And now the time is ripe for more systematic observations, and we find at Oxford William Merle, a Fellow of Merton College, to whom remains the distinction of being the first man in the Occidental world to keep a regular journal of the weather day by day. It embraces the years 1337 till 1344. The journal was wholly forgotten; but reading in an old volume of the *Philosophical Transactions* (1685), I came on a passage stating that such a journal of the weather is preserved at the Bodleian Library. I at once wrote to my late friend, Mr. G. J. Symons, asking him to look for this precious MS., and to publish it, if it should be found. And he did so. He published in 1891 the earliest known journal of the weather, kept at Oxford and later at Driby in Lincolnshire, where William Merle was Rector.

These recorded weather observations, of which I show as a specimen the months of November and December 1341 (Fig. 6), are not

FIG. 6.—Specimen of Merle's Journal, November and December 1341.

the original journal jotted down from day to day, or week to week, as time passed on. Had it been so there would have been far greater variation than there is in the size and character of the letters. The MS. represents only a résumé of the daily entries.

A close examination of the circumstances forces me to the conclusion that William Merle was induced to make regular observations by the desire to ascertain the correctness of the prognostics made by himself and his colleagues at Oxford where meteorology, or, more properly speaking, astro-meteorology, had been flourishing since the time of Robert Grosseteste, the famous Bishop of Lincoln. Merle himself has left behind two MSS. on the forecasting of the weather, and his contemporaneous Fellow of Merton College, John Eschendon (or Ashendon), whose name has been corrupted into Eschuid, completed in 1348 a voluminous treatise of astro-meteorology bearing the title *Summa judicialis de accidentibus mundi*. It was printed at Venice in 1489, and served in the sixteenth century as a text-book at the University of Vienna. The work is usually quoted in meteorological literature under the abbreviated title, *Summa Anglicana*, and is now extremely rare.

When, eighteen years ago, the journal of William Merle was rediscovered, it seemed to stand all alone, since we had no knowledge of other observations made in England or abroad. But recently I have been able to find out a nearly continued sequence of series of such observations, and to prove that from the fourteenth to the middle of the seventeenth centuries, namely, till the invention of meteorological instruments, the weather has been regularly observed in many places in Central and Western Europe.

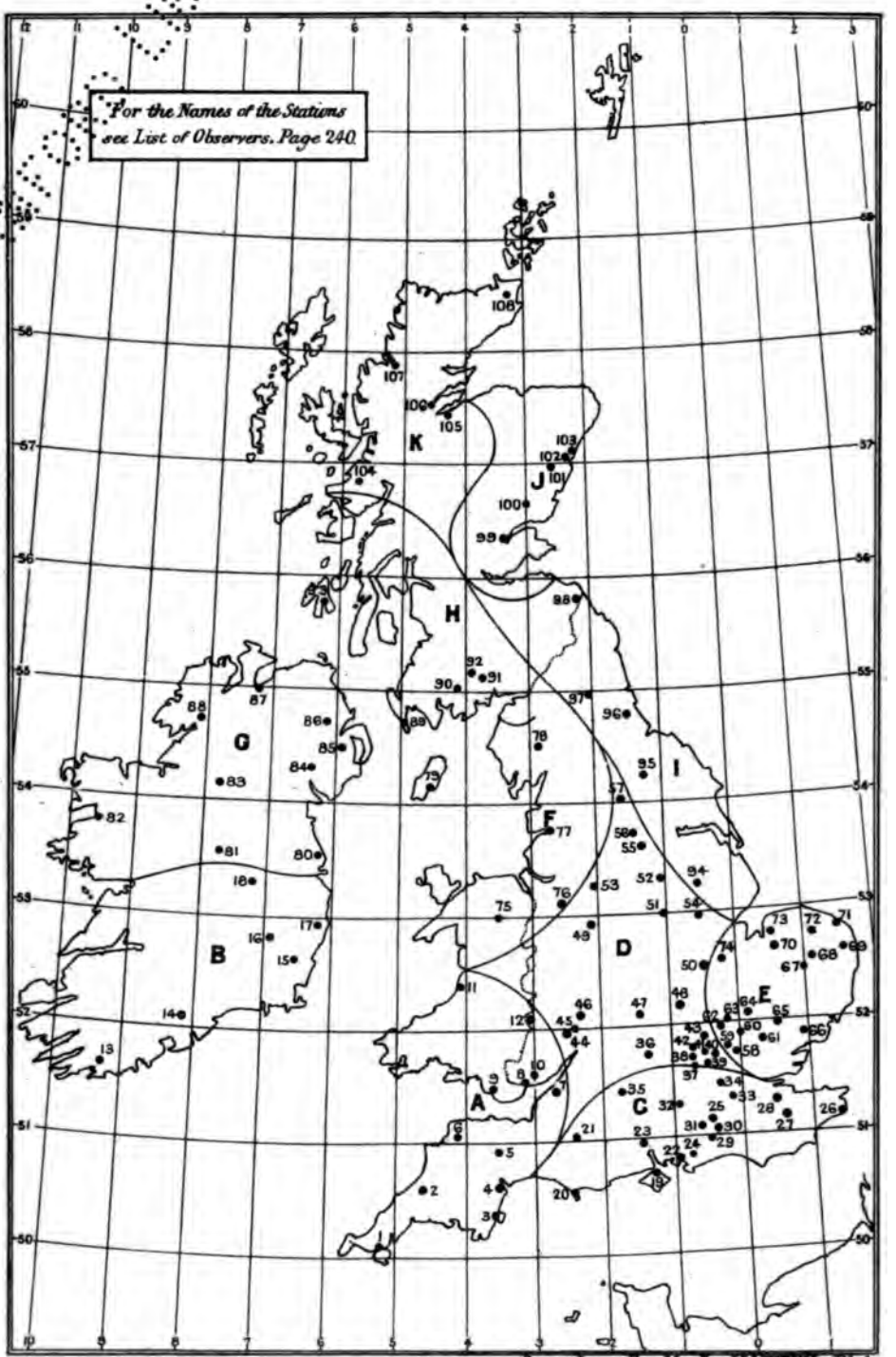
I had noticed that some copies of the large astronomical work, published in 1499 by Justus Stoeffler and Jacob Pflaum at Tübingen, *Almanach nova plurimis annis venturis inservientia*, containing ephemerides for the years 1499 to 1531, were full of meteorological entries written on the broad margins. This induced me to make systematic inquiry into copies of the work named containing such entries preserved in the great libraries of Germany, Austria, and Switzerland. The result of this inquiry was rather astonishing. No less than 123 different series of meteorological observations belonging to the fifteenth, sixteenth, and seventeenth centuries were dug out. Considering that this number of necessity represents but a small proportion, and concerns only some parts of Central Europe, we may safely presume that in the whole of Europe their number must have been far greater. Some of these early series of weather-observations are even corresponding ones, made by agreement.

A fresh stimulus for observing came at the end of the fifteenth century from quite another direction. The great discoveries of new lands and seas considerably enlarged and widened old ideas and conceptions. Atmospheric phenomena never seen before came to the knowledge of man, and climates very different to those at home became known. Intelligent men were struck by such varieties, and we can clearly observe their effect on them in the writings of that epoch. Luis de Camões, the famous Portuguese poet, described in his epos, *Os Lusiadas*, for the first time minutely the water-spouts often observed by him off the coast of Guinea and the storms in the South Indian Ocean, while from the logbook kept by Christopher Columbus during his first voyage we learn the deep impression he got from the difference of climate and weather in the Atlantic beyond the Azores compared with that eastwards of the islands. Such new observations advanced mostly the doctrine of the winds, which was now more fully expounded in Spanish and Portuguese works, until in the year 1622 Francis Bacon was the first to publish a special treatise dealing entirely with the winds.

But meanwhile experimental science, the growing up of which I have just alluded to, was so much developed that in the first half of the seventeenth century the principal meteorological instruments were invented. To Italy belongs the glory of being the native country of instrumental meteorology, the cradle of which stood at Florence. These inventions proved the first step in making meteorology a science, and now the shadows of the dawn are fast disappearing before the full light of the rising sun.

ANNUAL CHECK

MAP SHOWING POSITION OF THE PHENOLOGICAL STATIONS, 1907.



Quart. Journ. Roy. Met Soc. Vol. XXXIV. Pl. 4.

REPORT ON THE PHENOLOGICAL OBSERVATIONS FOR 1907.

By EDWARD MAWLEY, F.R.Met.Soc., V.M.H.

(Plate 4.)

[Read April 15, 1908.]

The following changes have taken place in the observing stations since the last Report was issued. No returns were received during the year from Sidcot and St. Arvans in District **A**; Churt and Bagshot in District **C**; Roxton in District **E**; Birkdale (Southport) and Lake Side in District **F**; and Blyth in District **I**. On the other hand, new stations have been started at Whitney-on-Wye in District **A**; Weymouth and Ditton Hill in District **C**; Dymock, King's Langley, Stone, and Kelton in District **D**; Ambleside in District **F**; and West Foulden in District **I**. The total number of observing stations is now 109.

TABLE I.—Mean Results, with their Variations from the 17 Years' Average (1891-1907), for the Thirteen Plants in those Districts where there have been sufficient Observations to warrant Comparisons being made.

Years.	Eng. S.W.		Eng. S.		Eng. Mid.		Eng. E.		Eng. N.W.	
	Day of Year.	Variation from Average.	Day of Year.	Variation from Average.	Day of Year.	Variation from Average.	Day of Year.	Variation from Average.	Day of Year.	Variation from Average.
		Days.		Days.		Days.		Days.		Days.
1891	144	+ 9	144	+ 8	150	+11	147	+10	150	+ 6
1892	139	+ 4	138	+ 2	144	+ 5	143	+ 6	147	+ 3
1893	118	-17	122	-14	125	-14	123	-14	128	-16
1894	126	- 9	130	- 6	135	- 4	127	-10	137	- 7
1895	139	+ 4	138	+ 2	141	+ 2	138	+ 1	144	0
1896	125	-10	128	- 8	132	- 7	130	- 7	134	-10
1897	130	- 5	132	- 4	136	- 3	132	- 5	142	- 2
1898	133	- 2	135	- 1	138	- 1	136	- 1	141	- 3
1899	136	+ 1	136	0	141	+ 2	138	+ 1	145	+ 1
1900	142	+ 7	141	+ 5	144	+ 5	143	+ 6	152	+ 8
1901	138	+ 3	139	+ 3	141	+ 2	139	+ 2	144	0
1902	139	+ 4	140	+ 4	145	+ 6	142	+ 5	152	+ 8
1903	134	- 1	134	- 2	137	- 2	134	- 3	145	+ 1
1904	139	+ 4	139	+ 3	142	+ 3	140	+ 3	149	+ 5
1905	133	- 2	135	- 1	138	- 1	136	- 1	144	0
1906	135	0	134	- 2	138	- 1	137	0	143	- 1
1907	142	+ 7	139	+ 3	143	+ 4	142	+ 5	149	+ 5
Mean	135	...	136	...	139	...	137	...	144	...

Explanation of the Dates in the Tables.

1- 31	are in	January.	182-212	are in	July.
32- 59	,,	February.	213-243	,,	August.
60- 90	,,	March.	244-273	,,	September.
91-120	,,	April.	274-304	,,	October.
121-151	,,	May.	305-334	,,	November.
152-181	,,	June.	335-365	,,	December.

The averages, with which the mean dates of the different plants are compared in Table IV., have been obtained from the actual observations made during the 17 years 1891-1907 in all those districts where sufficient observations were available. Those for the two remaining districts are as near approximations to the true averages as the limited number of records will allow.

The Winter of 1906-7.

This was everywhere a cold and dry season, with an unusually good record of sunshine. The temperature was very variable, but the colder periods as a rule lasted much longer than those which were unseasonably warm. In all three months the rainfall was below the average. It was a remarkably sunny winter, especially in the midland, north-western, and north-eastern counties of England, and in the east of Scotland.

The accounts received from different parts of the country vary considerably, but in most districts, notwithstanding the frequent interruptions from rain and frost, good progress appears on the whole to have been made with the cultivation of the land for spring corn. During the last week in November, and the early part of December, wheat sowing, which had been stopped by the previous long period of heavy rain, was resumed, and under more favourable conditions than at any time since September. The autumn-sown cereals came up slowly but well, and continued to present a promising appearance throughout the winter. During the severe frosts which occurred for a short time towards the end of December, they were fortunately protected by a deep covering of snow, and when the frost had gone out of the ground the surface soil was made firm again by the moderately heavy rainfall which followed. Good progress was also made with ploughing the land in Scotland and the north of England, but the hindrances through rain and frost were there more frequent and prolonged.

Until destroyed by the Christmas frost an unusual number of flowers were still to be seen here and there in sheltered places in the gardens, throughout the winter, in the southern half of England. In the middle of January there occurred a dry period which was particularly favourable for transplanting fruit-trees, shrubs, roses, etc., as the soil had been rendered friable through the recent frosts, and was at the same time warm and moist, without being too wet. The preparation of the soil for the reception of spring garden crops was carried on with comparatively few interruptions, considering the variable character of the season.

The fertile flowers on the hazel, taking the country as a whole, made their appearance 5 days later than usual.

The song-thrush was first heard after the beginning of January, 1 day in advance of its average date.

The honey-bee was first seen to visit flowers 3 days late.

The Spring.

March proved warm, dry, and sunny, whereas both April and May were cold, wet, and cloudy. The frequency of the rainfall in April and May was more exceptional than the quantity which fell at any one time.

There was a splendid record of sunshine in March, and a very poor record in May, while in April the departures from the average duration were in most districts small.

During the dry periods in March a good deal of spring corn was sown with little labour, and in the most satisfactory manner. The next two months were moderately wet, but the ground so readily absorbed the rain which fell, that no sooner was the sowing of the spring cereals completed than the seeding of mangolds, swedes, and turnips was proceeded with, and for these crops a fine and moist tilth was readily obtained. The autumn-sown corn continued to make good growth, and at the end of the spring was as healthy and strong as could be wished, without being too forward. The pastures and meadows were unusually bare during the early part of the season, but before the end of May, favoured by the moderate temperatures and occasionally heavy rains, good progress had been made, while the undergrowth at that period was thicker than for many years past. In the colder parts of the British Isles the conditions for working the land and sowing spring corn and the root crops were almost as favourable as in the south.

As was the case on the farm, the seeds sown in the garden, as a rule, germinated slowly but regularly, scarcely any failing. There was a profusion of bloom on the lilacs, laburnums, and other flowering shrubs, while the flower clusters were exceptionally fine. The fruit-trees also were laden with blossom, but the continued cold and sunless weather prevented many of the flowers setting their fruit, and more particularly was this the case with the apple-trees, which happened to be in full bloom when the night frosts in May were most severe.

All the spring migrants on the list, except the garlic hedge mustard, which blossomed at its average date, flowered later than usual, the coltsfoot being 6 days late, the wood anemone, blackthorn and horse-chestnut 1 day late, and the hawthorn 5 days late.

Of the spring migrants included in the report, the swallow was 3 days late, the cuckoo 6 days late, the nightingale 4 days late, while the flycatcher made its appearance at its average date.

The wasp first appeared 1 day late, the small white butterfly 3 days early, and the orange-tip butterfly 5 days late.

The Summer.

Each of the summer months was cold, and in all but three districts the fall of rain was in excess of the average; but, as was the case in the previous season, it was rather the frequency of the rain than its exceptional heaviness at any one time which was a noteworthy feature of the season. The record of sunshine was deficient in each month, and more particularly in June.

Favoured by the frequent falls of rain in the early part of the season the crop of hay was a heavy one. Owing, however, to the continuance of the same wet, dull, and cold weather after the grass had been cut, it was in most cases gathered in in an indifferent condition. In fact, in the southern half of England the only really good hay appears to have been secured during a dry week in the middle of July. Notwithstanding the cold and sunless weather the corn crops continued to make

satisfactory and healthy growth. The roots also improved, and there was always a good crop of herbage in the pastures. The great drawback in a summer of such frequent rainfall was the difficulty of keeping under the plague of weeds, which, owing to the wet state of the ground, have seldom been at this season so much beyond control. The

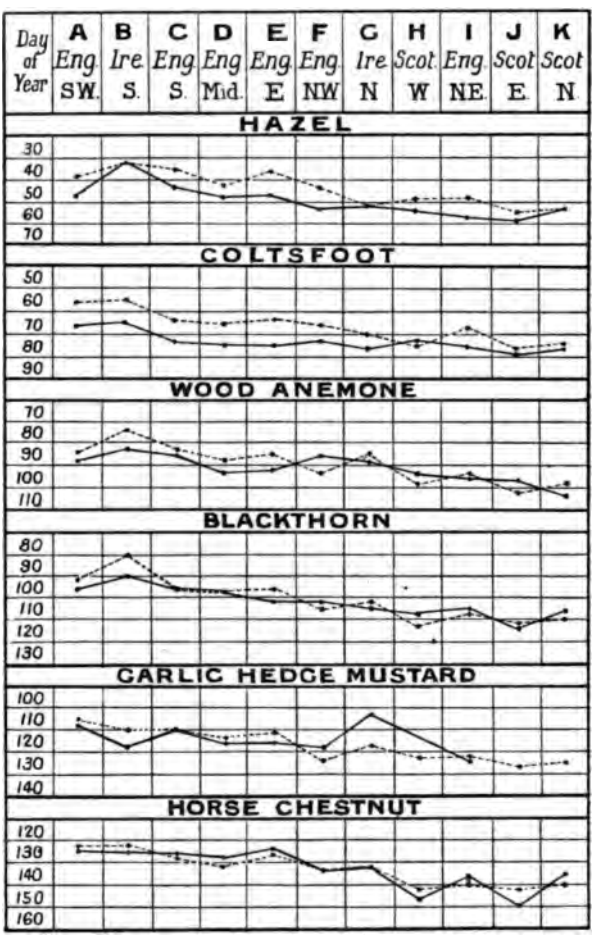


FIG. 1.

corn harvest was entered upon late, but in the most favourable weather possible, so that a good deal of corn had been harvested in excellent condition before the end of the summer. In the south of Scotland the interruptions to the hay harvest seem to have been less frequent than in others parts of the kingdom, so that a great part of the crop was gathered in under favourable circumstances. On the other hand, throughout the colder districts of these islands the sowing of turnips and swedes was

greatly delayed by wet weather, indeed in some parts of Scotland it was not completed until the middle of July. In Scotland oats, however, made good growth, particularly during the warm week in the middle of July, and promised at the end of the season to yield a heavy crop, both of grain and straw.

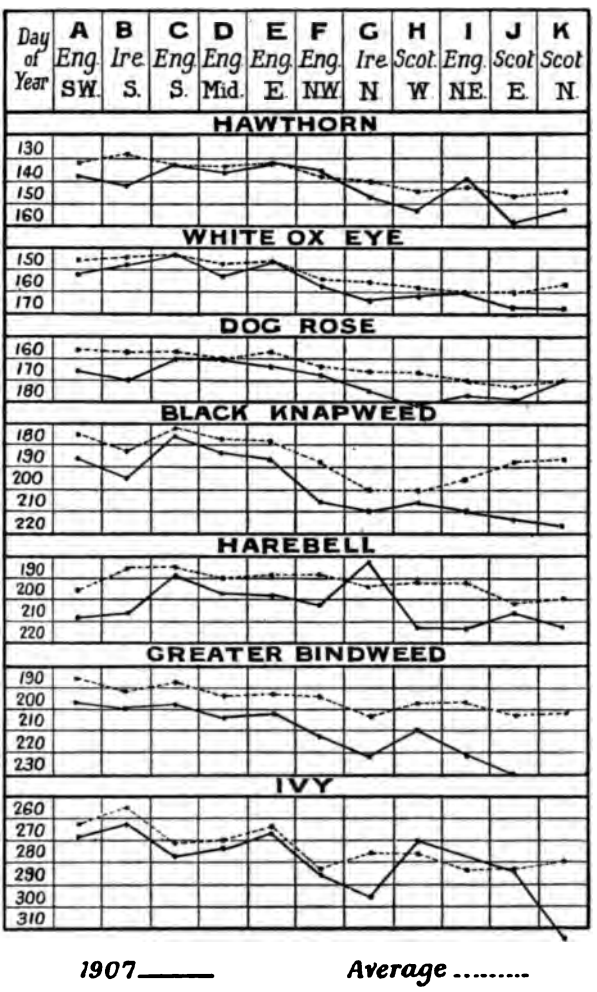


FIG. 2.

The cool weather and frequent rainfall which were such noteworthy features of the summer months suited the vegetables in the kitchen garden, and more particularly peas and beans, which made unusually good growth. The same conditions, however, were less favourable in the flower garden, the progress of many plants being kept in check by the cold state of the ground. Trees and shrubs, on the other hand, were greatly benefited by the continued moisture both above and below ground.

Owing to the coolness of the season the hawthorn and other flowering shrubs and trees remained a much longer time than usual in blossom. There was a noticeable scarcity of butterflies.

All the summer flowering plants on the list came into blossom behind their usual dates, the white ox-eye being 4 days late, the dog-rose 7 days late, the black knapweed 13 days late, the harebell 10 days late, and the greater bindweed 14 days late.

The meadow brown butterfly made its appearance 16 days later than usual.

The Autumn.

This was in all parts of the kingdom a warm autumn. September and November proved dry, whereas in October the rainfall was unusually heavy. September was a very sunny month, but taking the two other months together the record of sunshine was on the whole under average.

The fears of the previous season as to the further progress of the harvest were soon dispelled, for September proved a perfect harvest month, indeed after the first few days scarcely a drop of rain fell. Seldom have farmers in the southern half of England had such a splendid time for getting in a heavy yield of corn in such excellent condition, there being no sprouting or discoloration of the grain, while the straw was bright and also unusually abundant. In many cases, however, a good deal of the corn had previously been beaten down by heavy rains and high winds, and consequently had to be cut by hand, which made the harvest more tedious and expensive than it otherwise would have been. Throughout the greater part of the kingdom the harvest had been completed by the end of the third week in September. The cool wet weather in October favoured the root crops, which before the end of the season had made excellent growth. Potatoes, however, were in most districts found to have become much diseased when lifted. The pastures continued green throughout the autumn, notwithstanding the long spell of dry weather in September. The preparation of the land for the reception of the autumn cereals was much delayed owing to the late harvest, and again by the sodden condition of the ground during the last fortnight in October and the same period in November. For the first time since the winter the farmer was enabled to clear the land of weeds, which had grown almost unchecked throughout the whole of the spring and summer.

In the colder parts of Scotland the weather proved very trying to the farmers, for scarcely had a long and tedious hay harvest come to an end than the corn harvest began under equally unfavourable conditions. The crop of oats was a large one, but remained so long in the fields that when at last gathered in the grain was found to be discoloured, while much of it had sprouted. Potatoes in Scotland were small, but only to a moderate extent diseased.

Seldom have gardens been as gay with flowers, considering the time of year, as they were during the early part of this autumn, and owing to the absence of early frosts the flowering period has not often been as long extended. Vegetables of all kinds made unusually good growth, with the single exception of tomatoes, for which the summer had been much too cold and sunless. The early part of November proved an exceptionally favourable time for transplanting fruit-trees, shrubs, etc., as

the October rains had penetrated the ground to a sufficient depth to allow of the plants being taken up without injury to their roots, and replanted in their new quarters under the most favourable conditions. As was the case in the fields, there was a good deal of disease amongst the potatoes.

Trees held their foliage until an unusually late date, and the autumn tints were, as a rule, poor. There appears to have been an unusually small number of wasps and house-flies during this season.

The only autumn plant on the list, the ivy, came into flower 8 days later than its average date.

Taking the country as a whole, the last swallow took its departure 4 days later than its usual time.

According to the *Preliminary Statement* for Great Britain, issued by the Board of Agriculture, the yield of wheat per acre exceeded the average for the previous ten years by 2·74 bushels, barley by 2·12 bushels, beans by 5·00 bushels, and peas by 2·34 bushels. All these four crops were in each case with one exception heavier than in any year since official statistics were first collected, while that of oats was 3·75 bushels per acre above the ten years average, and heavier than in any year of the same period. Turnips and swedes exceeded the average by 0·98 ton, mangolds by 0·67 ton, hay (permanent pasture) by 3·24 cwts., and hay (clover, etc.) by 3·41 cwts. The only deficient crop was that of potatoes, which was 0·33 ton per acre below the average.

For the first time since Dr. Shaw directed attention to the close connection between the character of the autumn rainfall and the yield of wheat in the following year his conclusions failed to be confirmed by the result of the harvest. In the first place, in 1906, in five out of the eleven districts into which the country is divided, the autumn rainfall was in excess of the average, and then again the yield of wheat in 1907 was not only good, but the heaviest with one exception for many years.

The yield of fruit was variable, but on the whole poor. Apples, pears, and strawberries were decidedly under average both in size and quantity, but there was a good crop of plums, and a moderately good one of raspberries, currants, and gooseberries.

The Year.

The most noteworthy features of the weather of the phenological year ending November 1907, as affecting vegetation, were the cold and sunless character of April, May, and the three summer months, the frequent falls of rain during that period, the warm, dry, and sunny weather in September, and the heavy and continuous rainfall in October. Wild plants came into blossom behind their usual dates throughout the whole of the flowering season. Such early spring migrants as the swallow, cuckoo, and nightingale were also behind their average dates in reaching these Islands. The only deficient farm crop, taking the country as a whole, was that of potatoes, most of the other crops being much over average. On the other hand, the yield of apples and pears, and particularly the former, was below average. There was also a deficient crop of strawberries, whereas plums, raspberries, currants, and gooseberries were over average. As regards the farm crops it may be

TABLE II.—List of the Stations with the Names of the Observers.

Station.	County.	Height above Sea-level.	Observer.
		Ft.	
A			
1. Mawnan	Cornwall	200	Miss R. Barclay.
2. Altarnon	Cornwall	600	C. U. Tripp, M.A.
3. Brixham	Devon	40	F. W. Millett.
4. Starcross	Devon	50	P. G. Waterfield.
5. Tiverton	Devon	270	Miss M. E. Gill.
6. Barnstaple	Devon	90	T. Wainwright.
7. Clifton	Gloucester	300	G. C. Griffiths, F.E.S.
8. Penarth	Glamorgan	120	G. A. Birkenhead.
9. Bridgend	Glamorgan	90	H. J. Randall, Junr.
10. Little Mill	Monmouth	300	W. J. Grant, F.R.H.S.
11. Aberystwith	Cardigan	30	J. H. Salter, D.Sc.
12. Whitney-on-Wye.	Hereford	430	W. Burgess.
B			
13. Skibbereen	Cork	30	W. F. Wolfe.
14. Tallow	Waterford	...	Mrs. H. C. Deane.
15. Ferns	Wexford	260	G. E. J. Greene, M.A., D.Sc., F.L.S.
16. Bagenalstown	Carlow	290	Miss F. S. Wynne.
17. Ovoca	Wicklow	110	Miss W. F. Wynne.
18. Geashill	King's County	280	Rev. Canon Russell.
C			
19. Bembridge	Isle of Wight	80	C. Orchard, F.R.H.S.
20. Weymouth	Dorset	100	N. M. Richardson.
21. Buckhorn Weston	Dorset	290	Miss H. K. H. D'Aeth.
22. Havant	Hants	30	H. Beeston.
23. Botley	Hants	30	Lady Jenkyns.
24. Birdham	Sussex	10	A. J. Nixon.
25. Muntham	Sussex	250	P. S. Godman, F.Z.S.
26. Dover	Kent	150	F. D. Campbell.
27. Staplehurst	Kent	110	Rev. J. S. Chamberlain.
28. Maidstone	Kent	100	Mrs. Silcock.
29. Chiddingfold	Surrey	230	Admiral Maclear (the late).
30. Cranleigh	Surrey	180	Miss H. E. Ravenscroft.
31. Coneyhurst	Surrey	600	J. Russell.
32. Churt Vicarage	Surrey	350	Rev. A. W. Watson.
33. Purley	Surrey	350	J. E. Clark, F.R.Met.Soc.
34. Ditton Hill	Surrey	...	H. T. Potter.
35. Marlborough	Wilts	480	E. Meyrick, F.R.S.
D			
36. Oxford	Oxford	200	F. A. Bellamy, M.A., F.R.A.S.
37. Harefield	Middlesex	340	G. E. Eland.
38. Chesham	Bucks	300	Miss G. Keating.
39. Watford	Herts	270	Mrs. J. Hopkinson.
40. St. Albans (New Farm)	Herts	400	Miss A. Dickinson.
40. St. Albans (Glenferrie Road)	Herts	320	W. P. Westell, F.R.H.S., M.B.O.U.
41. King's Langley	Herts	400	M. Arnold.
42. Berkhamsted	Herts	400	Mrs. E. Mawley.
43. Harpenden	Herts	370	J. J. Willis.
44. Ross	Hereford	210	H. Southall, F.R.Met.Soc.
45. Dymock	Gloucester	120	Miss M. Peake.
46. West Malvern	Worcester	600	Mrs. Kensington.
47. Farnborough	Warwick	520	Miss D. J. G. Prater.
48. Northampton	Northampton	320	H. N. Dixon, M.A., F.L.S.

TABLE II.—List of the Stations with the Names of Observers—*continued.*

Station.	County.	Height above Sea-level.	Observer.
		Ft.	
49. Stone	Stafford	330	W. Wells Bladen.
50. Ketton	Rutland	290	Rev. A. H. Snowden.
51. Beeston	Notts	210	G. Fellows.
52. Hodsock	Notts	60	Miss Mellish, F.R.H.S.
53. Macclesfield	Cheshire	500	J. Dale.
54. Belton	Lincoln	200	Miss F. H. Woolward.
55. Altofts	Yorks (W.R.)	120	H. G. Townsend.
56. Horbury	Yorks (W.R.)	210	W. Rushforth.
57. Ripley	Yorks (W.R.)	240	Rev. W. T. Travis.
E			
58. Broxbourne	Herts	120	Rev. H. P. Waller.
59. Hatfield	Herts	380	Miss R. Blackett.
60. Hertford	Herts	140	W. Graveson.
61. Sawbridgeworth	Herts	350	H. S. Rivers.
62. Hitchin	Herts	220	A. W. Dawson, M.A.
63. Odsey (Ashwell)	Cambridge	260	H. G. Fordham.
64. Shelford	Cambridge	60	C. E. Smith.
65. Bocking	Essex	240	H. S. Tabor, F.R.Met.Soc.
66. Lexden	Essex	90	S. F. Hurnard.
67. Carleton-Forehoe	Norfolk	100	Rev. C. H. Master.
68. Tacolneston	Norfolk	190	Miss E. J. Barrow.
69. Eaton (Norwich)	Norfolk	100	A. W. Preston, F.R.Met.Soc.
70. Southacre	Norfolk	100	Rev. E. T. Daubeney.
71. Brunstead	Norfolk	30	Rev. M. C. H. Bird.
72. Hevingham	Norfolk	...	Major Marsham.
73. Clenchwarton	Norfolk	10	Miss E. M. Stevenson.
74. Peterborough	Northampton	30	J. W. Bodger.
F			
75. Llangollen	Merioneth	270	T. Ruddy.
76. Betley	Stafford	250	Miss M. L. Hodgson.
77. Preston	Lancashire	50	J. R. Charnley, F.G.S., F.Z.S.
78. Ambleside	Westmoreland	220	Miss Drury.
79. Cronkbourne	Isle of Man	110	A. W. Moore and J. Murphy.
G			
80. Ardgillan	Dublin	210	J. Woodward.
81. Edgeworthstown	Longford	270	J. M. Wilson, M.A.
82. Westport	Mayo	10	J. M. McBride.
83. Chanter Hill	Fermanagh	250	The Dean of Clogher.
84. Loughbrickland	Down	350	Rev. Canon Lett.
85. Saintfield	Down	310	Rev. C. H. Waddell, M.A.
86. Antrim	Antrim	70	Rev. W. S. Smith.
87. Altnafoyle	Londonderry	450	T. Gibson.
88. Milford	Donegal	150	Miss Osborne.
H			
89. Kirkmaiden	Wigtown	100	Rev. D. R. Williamson.
90. New Galloway	Kirkcudbright	450	T. R. Bruce.
91. Jardington	Dumfries	100	J. Rutherford.
92. Moniaive	Dumfries	350	J. Corrie.
93. Port Ellen	Isle of Islay	10	T. F. Gilmour.
I			
94. Doddington	Lincoln	90	Rev. R. E. Cole.
95. Thirsk	Yorks (N.R.)	120	A. B. Hall.
96. Durham	Durham	350	Prof. R. A. Sampson and F. C. H. Carpenter.

TABLE II.—List of the Stations with the Names of Observers—*continued.*

Station.	County.	Height above Sea-level.	Observer.
		Ft.	
97. Corbridge-on-Tyne	Northumberland	200	A. W. Price.
98. West Foulden .	Berwick . .	250	J. H. Craw.
J			
99. Forgandenny .	Perth . .	...	D. Nicoll.
100. Kirriemuir .	Forfar . .	250	T. M. Nicoll.
101. Durris . .	Kincardine .	420	A. Macdonald, M.A.
102. Crathes . .	Kincardine .	140	J. Smith, F.R.Met.Soc.
103. Aberdeen . .	Aberdeen .	40	P. Harper.
K			
104. Invermoidart .	Inverness . .	60	S. M. Macvicar.
105. Beauly . .	Inverness . .	60	A. Birnie.
106. Dingwall . .	Ross . .	10	J. P. Smith, M.D.
107. Inverbroom .	Ross . .	50	Lady Fowler.
108. Watten . .	Caithness . .	150	Rev. D. Lillie.

The numbers before the names of the stations refer to their position on the Map of the Stations. (Plate 4.)

stated that 1905 was a plentiful year, in 1906 the yield was even better, while the past year proved the most bountiful of the three.

Observers' Notes.

December 1906.—*Mawnan* (A)—1st. Broad beans have sent up a second growth from the roots which are now from two to three feet high and in full flower. *Altarnon* (A)—Wild geese, swans and other migrants usually numerous. *Penarth* (A)—1st. Geraniums and nasturtiums still flowering. 29th. Nasturtiums killed. *Whitney-on-Wye* (A)—21st. Cut some good roses. *Havant* (C)—Two sand-martins were seen in full vigour of flight on the 21st, but after that only one was seen, which remained until January 12, 1907. *Maidstone* (C)—30th. It has been so mild that many trees still hold their leaves. *Churt Vicarage* (C)—On Christmas Day chrysanthemums, violets, roses, and wallflowers were still in flower. *King's Langley* (D)—Gathered a good rose bloom on Christmas Day. *Ross* (D)—4th. Bat seen. *Hodsock* (D)—A great many berries on the holly. Two or three roses on the wall still in flower on Christmas Day. *Brunstead* (E)—9th. Trees struck by lightning during a snowstorm. *Birkdale (Southport)* (F)—18th. Holly berries not very plentiful. *Milford* (G)—16th. Bats flying.

January 1907—*Whitney-on-Wye* (A)—Brussel sprouts have suffered considerably from frost, and cabbages slightly. *Betley* (F)—31st. Some wild flowers still out in sheltered spots.

February—*Altarnon* (A)—12th. Wallflowers crippled by recent winds and frost. *Whitney-on-Wye* (A)—14th. The birds have cleared off all the holly berries. *Ovoca* (B)—24th. Frog spawn first seen. *Buckhorn Weston* (C)—Vegetation remarkably late owing to frosts in January and at times in February. *Botley* (C)—Many redwings and fieldfares. *Churt Vicarage* (C)—Fieldfares

TABLE III.—Date (Day of Year) of First Flowering of Plants, 1907.

Station.	Hazel.	Coltsfoot.	Wood Anemone.	Blackthorn.	Garlic Hedge-Mustard.	Horse-Chestnut.	Hawthorn.	White Ox-Eye.	Dog Rose.	Black Knapweed.	Harebell.	Greater Bindweed.	Ivy.
A													
Mawnan . .	52	78	91	101	...	128	137	...	...	...	...	...	258
Altarnon . .	*72*	79	108	109	127	134	155	167	171	206	212	*237*	255
Brixham . .	58	77	...	81	...	119	133	...	173	...	...	201	274
Starcross . .	...	52	...	83	112	116	*115*	149	155	164	...	180	263
Tiverton . .	47	65	88	92	106	126	140	...	...	...	...	...	277
Barnstaple . .	18	57	90	97	98	120	136	159	169	194	212	196	271
Clifton . .	...	...	...	102	...	121	132	...	...	...	...	...	...
Bridgend . .	*62*	71	86	111	121	135	142	161	171	185	208	...	270
Little Mill . .	47	58	81	84	99	105	126	138	159	173	...	178	*245*
Aberystwith .	49	57	89	92	102	128	129	138	164	188	203	204	263
Whitney-on-Wye.	52	...	83	105	...	...	134	146	168	195	210	222	292
B													
Skibbereen . .	29	...	69	90	...	...	...	...	...	...	...	...	...
Tallow . .	...	*3*	...	83	...	105	*111*	...	164	201	...	200	267
Ferns . . .	*61*	80	98	91	...	*96*	135	149	170	206	231	*231*	257
Bagenalstown .	...	78	...	95	...	131	143	...	...	207	...	...	...
Ovoca . . .	21	47	81	80	...	131	138	145	...	204	...	...	...
Geashill . .	42	56	80	96	119	133	148	151	176	161	180	...	...
C													
Bembridge . .	*62*	60	...	99	118	117	126	133	160	164	...	...	...
Weymouth . .	...	...	89	93	...	129	...	...	174	...	...	209	272
Buckhorn Weston	47	72	82	100	101	131	132	141	161	172	...	199	269
Havant . .	18	79	...	95	98	134	...	143	146	166	...	200	275
Botley . .	50	79	77	103	125	131	133	147	174	*196*	...	...	288
Birdham . .	48	...	...	67	112	119	131	138	161	185	...	...	...
Muntham . .	47	76	85	98	103	129	131	143	152	176	...	188	285
Dover . . .	...	*91*	...	91	...	127	141	...	166	193	...	...	280
Staplehurst . .	51	76	81	94	100	115	126	133	147	167	183	185	...
Maidstone . .	55	63	88	103	106	126	130	135	151	168	...	201	257
Chiddingfold .	49	76	86	95	109	120	135	138	...	...	...	...	...
Cranleigh . .	46	...	85	89	112	125	134	141	156	*209*	...	193	283
Coneyhurst . .	57	87	86	99	...	129	134	149	164	194	189	192	277
Churt Vicarage .	32	...	...	103	112	126	132	147	161	179	182	214	...
Purley . .	61	61	89	102	122	125	133	146	161	...	...	...	...
Ditton Hill . .	...	81	...	106	111	125	131	146	162	179	...	213	285
Marlborough .	15	73	83	93	109	129	134	153	160	166	203	183	...
D													
Oxford . .	...	75	90	93	96	121	137	146	152	...	...	...	268
Harefield . .	62	88	90	103	...	127	131	...	153	198	210	206	...
Chesham . .	56	78	94	102	124	133	137	*162*	166	165	...	199	267
Watford . .	46	76	...	95	104	125	130	146	162	...	193	...	275
St. Albans (New Farm)	22	78	90	94	114	...	130	151	153	200	185	...	272
St. Albans (Glenferrie Road)	20	88	89	90	108	132	140	153	159	171	...	215	286
King's Langley .	61	...	...	98	...	132	134	152	167	...	...	...	...
Berkhamsted .	57	79	104	104	114	130	141	146	158	197	208	201	267

TABLE III.—Date (Day of Year) of First Flowering of Plants, 1907—*continued.*

Station.	Hazel.	Coltsfoot.	Wood Anemone.	Blackthorn.	Garlic Hedge-Mustard.	Horse-Chestnut.	Hawthorn.	White Ox-Eye.	Dog Rose.	Black Knapweed.	Harebell.	Greater Bindweed.	Ivy.
Harpenden	53	75	103	102	114	130	137	149	163	171	...	...	...
Ross	47	61	89	*84*	106	115	127	...	153	...	...	...	...
Dymock	...	77	87	105	106	...	134	...	159	167	...	...	275
West Malvern	58	68	*58*	102	99	128	132	158	161	171	191	202	*227*
Farnborough	17	63	94	92	114	137	135	146	161	187	...	213	273
Northampton	60	80	84	94	122	129	131	148	160	177	181	211	264
Stone	...	...	...	...	...	141	140	...	...	...	...	...	...
Ketton	...	...	...	...	...	...	...	...	160	...	...	...	264
Beeston	...	79	...	108	130	128	132	156	...	194	*157*	...	...
Hodsock	52	76	90	97	115	119	131	162	172	202	200	192	274
Macclesfield	60	88	119	114	137	144	145	165	173	189	190	197	276
Belton	39	61	82	93	129	131	133	154	154	191	201	208	276
Altofts	62	...	89	...	117	124	124	...	...	...	...	...	...
Horbury	...	71	84	...	118	124	134	*190*	...	...	217	...	...
Ripley	...	59	...	...	125	133	149	...	...	...	...	...	...
E													
Broxbourne	46	71	96	...	114	...	...	...	161	...	...	...	263
Hatfield	56	...	92	...	...	...	129	145	153	...	209	...	...
Hertford	34	69	83	83	97	129	132	142	167	181	204	*180*	265
Sawbridgeworth	49	75	...	107	...	...	...	...	168	...	...	...	...
Hitchin	...	...	...	...	...	127	130	...	155	...	...	...	...
Odsey (Ashwell)	18	83	...	...	...	...	130	...	158	...	...	...	274
Shelford	35	...	...	113	...	127	130	132	*135*	...	*166*	...	...
Bocking	47	81	89	100	121	118	130	144	154	210	209	218	273
Lexden	61	87	105	106	121	125	130	137	157	179	197	190	271
Carleton-Forehoe	45	82	100	106	111	129	133	153	167	182	206	...	270
Tacolneston	53	76	90	...	...	109	131	152	164	172	...	203	...
Eaton (Norwich)	58	...	...	...	125	127	132	149	168	...	...	211	...
Southacre	...	61	83	92	104	128	132	152	167	169	173	197	258
Brunstead	56	...	...	110	112	132	134	155	167	210	204	213	...
Hevingham	...	...	85	...	...	...	128	...	...	...	...	...	...
Clenchwarton	...	65	...	...	130	127	131	...	162	*226*	...	191	257
Peterborough	49	71	86	91	111	119	131	143	162	187	191	197	283
F													
Langollen	50	56	87	91	110	126	131	145	163	205	201	208	284
Betley	46	77	85	105	107	137	137	165	167	206	208	217	300
Preston	...	84	...	...	...	...	...	...	...	...	...	...	...
Ambleside	57	...	...	106	127	133	145	164	173	207	200	...	277
Cronkbourne	58	...	*116*	...	133	131	137	156	...	...	...	*238*	281
G													
Ardgillan	56	71	86	104	...	123	148	159	173	*226*	...	229	306
Edgeworthstown	...	...	87	112	...	139	147	...	169	...	...	...	...
Westport	36	...	*57*	105	...	111	145	...	165	...	...	...	...
Chanter Hill	46	61	88	89	104	134	144	162	177	200	182	229	285
Loughbrickland	54	81	105	116	...	140	145	...	176	...	...	229	...
Saintfield	60	80	91	105	...	137	152	167	177	...	...	...	...
Antrim	66	...	83	...	104	...	143	164	181	210	...	199	...

TABLE III.—Date (Day of Year) of First Flowering of Plants, 1907—*continued.*

Station.	Hazel.	Coltsfoot.	Wood Anemone.	Blackthorn.	Garlic Hedge-Mustard.	Horse-Chestnut.	Hawthorn.	White Ox-Eye.	Dog Rose.	Black Knapweed.	Harebell.	Greater Bindweed.	Ivy.
Altnafoyle	61	79	...	113	...	134	149	...	175	220	...	...	...
Milford	31	82	85	89	...	129	148	163	184	...	...	*266*	295
H													
Kirkmaiden	55	46	94	117	...	146	150	168	171	...	211	199	270
New Galloway	46	82	98	*125*	...	153	163	*175*	184	*222*	209	...	...
Jardington	59	88	89	113	...	142	151	157	181	210	203	...	...
Moniaive	*70*	...	92	116	...	146	158	161	188	203	...	221	...
Port Ellen	54	...	...	92	...	...	144	...	...	...	...	...	...
I													
Doddington	64	84	97	101	127	127	133	...	163	...	...	...	...
Thirsk	49	58	88	104	118	133	135	158	177	203	210	221	...
Durham	57	79	99	110	...	...	...	...	...	...	...	...	...
Corbridge-on-Tyne	...	81	...	109	*135*	151	148	...	...	...	...	...	...
West Foulden	...	...	...	...	...	...	...	162	191	216	214	...	...
J													
Forgandenny	...	78	*138*	...	...	161	161	...	...	...	...	...	...
Kirriemuir	...	...	...	113	...	...	157	173	172	215	199	...	...
Durris	59	79	88	114	...	134	...	168	175	208	212	230	283
Crathes	...	...	93	116	...	...	...	159	177	...	...	...	*343*
Aberdeen	...	80	109	...	...	155	159	...	196	...	*232*	...	...
K													
Invermoidart	...	...	111	...	...	...	152	169	174	...	...	...	...
Beauly	51	...	114	118	...	144	151	170	171	201	215	...	314
Dingwall	56	73	88	103	...	131	147	167	173	...	209	...	...
Inverbroom	*25*	79	...	104	...	133	...	...	161	...	...	...	...
Watten	...	76	...	...	...	...	165	*200*	...	232	...	...	...

The dates in *italics* have not been taken into consideration when calculating the means given in Table IV.

more numerous than for many years past. *Harefield* (D)—27th. Bat first seen. *Berkhamsted* (D)—11th. Winter aconite in flower—23 days later than its average date for the previous 20 years, and later than in any year since 1891. *Odsey* (E)—28th. Rooks began to build. *Llangollen* (F)—Wallflowers much injured by frost. *Thirsk* (I)—25th. Rooks building.

March.—*Mawnan* (A)—1st. Veronicas, geraniums, and calceolarias in some part of garden killed by the January and February frosts. *Altarnon* (A)—At the end of the month on light soils pastures were becoming bare. *Aberystwith* (A)—26th. Small bats first seen. *Whitney-on-Wye* (A)—16th. Frog spawn first seen. *Ovoca* (B)—Autumn-sown peas destroyed by frost. *Berkhamsted* (D)—22nd. An early Rivers' peach on a south wall in blossom 1 day earlier than its average date in the previous 21 years. *Harpenden* (D)—8th. Rooks building. *Ripley* (D)—30th. Willow warbler first heard. *Cronkbourne* (F)—25th. Oat-sowing commenced. *Thirsk* (I)—20th. Frog spawn first seen.

TABLE IV.—MEAN DATES (DAY OF YEAR) FOR THE FIRST FLOWERING OF 13 PLANTS IN 1907, AND THEIR VARIATIONS FROM THE 17 YEARS' AVERAGE, 1891-1907.

PLANTS.	A England, S.W.			B Ireland, S.			C England, S.			D England, Mid.		
	1907.	Average for 17 Years.	Variation from Average.	1907.	Average for 17 Years.	Variation from Average.	1907.	Average for 17 Years.	Variation from Average.	1907.	Average for 17 Years.	Variation from Average.
Hazel	46	39	+ 7	31	31	0	44	35	+ 9	48	42	+ 6
Coltsfoot	66	56	+ 10	65	55	+ 10	74	63	+ 11	75	65	+ 10
Wood Anemone	89	85	+ 4	82	74	+ 8	85	83	+ 2	92	89	+ 3
Blackthorn	96	91	+ 5	90	80	+ 10	96	96	0	99	99	0
Garlic Hedge-Mustard	109	107	+ 2	119	110	+ 9	110	110	0	115	114	+ 1
Horse-Chestnut	123	121	+ 2	125	121	+ 4	126	127	− 1	129	131	− 2
Hawthorn	137	131	+ 6	141	129	+ 12	132	132	0	135	134	+ 1
White Ox-Eye	151	146	+ 5	148	143	+ 5	142	142	0	152	149	+ 3
Dog Rose	166	156	+ 10	170	158	+ 12	160	158	+ 2	160	160	0
Black Knapweed	186	175	+ 11	196	182	+ 14	176	172	+ 4	184	178	+ 6
Harebell	209	195	+ 14	206	*186*	+ 20	189	185	+ 4	198	190	+ 8
Greater Bindweed	197	186	+ 11	200	191	+ 9	198	189	+ 9	203	192	+ 11
Ivy	269	264	+ 5	262	255	+ 7	277	271	+ 6	272	270	+ 2
Mean for the 13 Plants	142	135	+ 7	141	132	+ 9	139	136	+ 3	143	139	+ 4

PLANTS.	E England, E.			F England, N.W.			G Ireland, N.			H Scotland, W.		
Hazel	47	36	+ 11	53	44	+ 9	51	51	0	53	49	+ 4
Coltsfoot	75	63	+ 12	72	66	+ 6	76	70	+ 6	72	74	− 2
Wood Anemone	91	87	+ 4	86	93	− 7	89	86	+ 3	93	99	− 6
Blackthorn	101	98	+ 3	101	104	− 3	104	101	+ 3	109	112	− 3
Garlic Hedge-Mustard	115	111	+ 4	119	124	− 5	104	*119*	− 15	...	*122*	...
Horse-Chestnut	125	126	− 1	132	132	0	131	131	0	147	142	+ 5
Hawthorn	131	131	0	137	138	− 1	147	140	+ 7	153	144	+ 9
White Ox-Eye	146	146	0	157	153	+ 4	163	156	+ 7	162	159	+ 3
Dog Rose	162	157	+ 5	168	162	+ 6	175	166	+ 9	181	166	+ 15
Black Knapweed	186	179	+ 7	206	189	+ 17	210	200	+ 10	207	200	+ 7
Harebell	199	189	+ 10	203	189	+ 14	182	*194*	− 12	212	191	+ 21
Greater Bindweed	202	192	+ 10	212	194	+ 18	221	203	+ 18	210	*198*	+ 12
Ivy	268	265	+ 3	285	282	+ 3	295	277	+ 18	270	*277*	− 7
Mean for the 13 Plants	142	137	+ 5	149	144	+ 5	150	146	+ 4	156*	151*	+ 5*

PLANTS.	I England, N.E.			J Scotland, E.			K Scotland, N.			British Isles.		
Hazel	57	49	+ 8	59	*55*	+ 4	53	*53*	0	49	44	+ 5
Coltsfoot	75	68	+ 7	79	*77*	+ 2	76	*75*	+ 1	73	67	+ 6
Wood Anemone	95	94	+ 1	97	*101*	− 4	104	*99*	+ 5	91	90	+ 1
Blackthorn	106	108	− 2	114	*113*	+ 2	108	*110*	− 2	102	101	+ 1
Garlic Hedge-Mustard	122	121	+ 1	..	*127*	...	...	*125*	...	114	114	0
Horse-Chestnut	137	140	− 3	150	*142*	+ 8	136	*140*	− 4	133	132	+ 1
Hawthorn	139	142	− 3	159	*146*	+ 13	154	*144*	+ 10	142	137	+ 5
White Ox-Eye	160	160	0	167	*160*	+ 7	169	*158*	+ 11	156	152	+ 4
Dog Rose	177	170	+ 7	180	*172*	+ 8	170	*170*	0	170	163	+ 7
Black Knapweed	210	196	+ 14	212	*189*	+ 23	216	*187*	+ 29	199	186	+ 13
Harebell	212	191	+ 21	205	*202*	+ 3	212	*200*	+ 12	202	192	+ 10
Greater Bindweed	221	198	+ 23	230	*203*	+ 27	...	*201*	...	209	195	+ 14
Ivy	...	282	...	283	*282*	+ 1	314	*280*	+ 34	280	272	+ 8
Mean for the 13 Plants	143*	136*	+ 7*	161*	*153**	+ 8*	156†	*147*†	+ 9†	148	142	+ 6

* For 12 Plants. † For 11 Plants.

\+ indicates the number of days later than the average date.
− ,, ,, ,, earlier ,, ,,
o ,, average date (1891-1907).
The dates in *italics* are approximate averages.

APRIL.—*Mawnan* (A)—1st. All our large marguerites are now dead. *Altarnon* (A)—Apples, pears, etc., showing luxuriant blossom. *Whitney-on-Wye* (A)—Growth in gardens very slow. *Bembridge* (C)—Plums and pears full of blossom. *Chiddingfold* (C)—26th. Blackthorn, wild cherry, and pear in remarkably profuse bloom. 30th. Grass in pastures short for the time of year. *Coneyhurst* (C)—26th. Sand-martin first seen. *Churt Vicarage* (C)—1st. Wryneck first heard. 10th. White-throat first seen. *Berkhamsted* (D)—14th. A wild cherry in my garden came into flower 5 days in advance of its average date in the previous 21 years. *Harefield* (D)—17th. Wryneck first heard. *Macclesfield* (D)—18th. Blossom on early plums destroyed by frost. *Ripley* (D)—11th. Sand-martin first seen. *Llangollen* (F)—Abundant blossom on wild cherry trees. *Corbridge-on-Tyne* (I)—Cuckoos not so numerous as usual, and it was longer before they changed their note. 28th. House-martin seen. 29th. Sand-martin seen. *Durris* (J)—13th. Sand-martin first seen. 22nd. House-martin first seen.

MAY.—*Altarnon* (A)—22nd. The frosts of the last few nights have killed rhododendron blossom and all the young shoots of the ivy, nettle, etc. *Whitney-on-Wye* (A)—22nd. Potatoes and runner beans blackened by frost. *Ovoca* (B)—In the third week potatoes blackened by sharp frosts. Hawthorn blossom abundant. *Weymouth* (C)—27th. The oaks have been in full leaf for some time, but the ashes only show the least sign of leaves at the tips of the branches. *Botley* (C)—Oaks quite free from caterpillars. Hardly any nightingales. 16th. Flowering shrubs exceptionally full of blossom. *Churt Vicarage* (C)—21st. The night frosts have done much damage to all fruit blossom. Gooseberries dropping off the bushes in the lower part of the parish. 21st. May-fly first seen. *Purley* (C)—18th. Walnut-trees in the Brighton valley below my house blackened by frost. *Oxford* (D)—24th. Chestnut blossoms beginning to fall. Owing to the cool weather they have lasted over three weeks. *Berkhamsted* (D)—4th. A Blenheim orange apple in my garden came into blossom 2 days earlier than its average date in the previous 21 years. *Dymock* (D)—An unusual number of queen wasps. 21st. Potatoes blackened by frost. *Macclesfield* (D)—24th. Ash-trees as yet quite leafless. *Tacolneston* (E)—Abundant blossom on the hawthorns. 10th. House-martin first seen. *Southacre* (E)—30th. Owing to the absence of sun the continued rain has begun to damage the crops. *Clenchwarton* (E)—30th. Blossom on hawthorn unusually abundant. *Llangollen* (F)—24th. Potatoes much injured by frost on the south side of the town, but only slightly injured on north side. *Durris* (J)—Fruit-trees flowering profusely.

JUNE.—*Altarnon* (A)—13th. Rapid growth of weeds. *Whitney-on-Wye* (A)—3rd. After the gale the ground was strewn with leaves as in winter. *Churt Vicarage* (C)—5th. Queen wasps very numerous this year. 11th. All flowering trees such as horse chestnut, laburnum, and hawthorn unusually beautiful this year. *Oxford* (D)—26th. Scarcely any grass has been cut. *Harpenden* (D)—17th. First wheat-ear out of sheath, or 4 days later than the average date for the previous 15 years. *Harefield* (D)—8th. Hay first cut. *Southacre* (E)—30th. Hawthorn still in bloom. *Clenchwarton* (E)—29th. A great many slugs and snails. *Llangollen* (F)—Vegetation almost at a standstill. *Betley* (F)—23rd. Hay cut because it was rotting near the ground. *Westport* (G)—1st. Hawthorn blossom completely ruined by hail. *Moniaive* (H)—Vegetation at the end of month at a standstill.

JULY.—*Whitney-on-Wye* (A)—Some good hay harvested between 14th and 20th. *Botley* (C)—An unusual number of swifts. Most butterflies and moths scarce. *Bembridge* (C)—7th. Sufficient snow fell for boys to make snowballs—a "record" for July. *West Malvern* (D)—5th. A hawthorn on the Malvern Hills now in full flower. *Farnborough* (D)—15th. Cuckoo last heard—ten days

TABLE V.—Date (Day of Year) of Song and Migration of Birds, and First Appearance of Insects, 1907.

Station.	Song.	Migration.					Insects.				
	Song-Thrush first heard.	Swallow first seen.	Cuckoo first heard.	Nightingale first heard.	Flycatcher first seen.	Swallow last seen.	Honey Bee.	Wasp.	Small White Butterfly.	Orange Tip Butterfly.	Meadow Brown Butterfly.
A											
Mawnan	7	104	105	...	127	279	62	...	88	133	195
Altarnon	7	104	102	...	130	286	47	114	87	117	159
Brixham	13	113	126	...	...	292	...	...	108	...	193
Starcross	...	100	115	...	*154*	284	65	84	91	124	159
Tiverton	...	...	...	...	...	...	61	...	...	...	...
Clifton	...	106	...	...	...	...	...	*21*	63	...	...
Penarth	...	...	...	...	...	...	81	104	91	132	202
Bridgend	6	110	126	...	...	285	72	128	*133*	...	180
Little Mill	14	108	113	125	130	282	15	76	78	*96*	*124*
Aberystwith	8	104	125	...	131	*268*	...	80	88	117	180
Whitney-on-Wye	...	91	115	...	...	...	56	91	120	128	181
B											
Skibbereen	15	101	...	...	...	...	*3*	...	104	...	...
Tallow	...	99	...	...	...	...	79	...	...	...	...
Ferns	5	105	124	...	...	304	65	110	113	114	*114*
Bagenalstown	16	104	115	...	*110*	281	47	105	94	115	...
Ovoca	*38*	112	125	...	...	276	56	86	106	114	131
Geashill	...	102	127	...	...	290	53	*155*	116	130	...
C											
Bembridge	9	90	110	105	...	307	62	62	86	147	...
Weymouth	...	113	115	...	137	303	60	*10*	81	158	181
Buckhorn Weston	5	106	106	...	133	289	62	...	83	*104*	172
Havant	9	92	104	107	144	321	...	...	80	127	179
Botley	9	103	104	126	137	292	42	63	93	134	194
Birdham	9	88	103	112	...	331	18	...	...	119	...
Muntham	15	103	105	113	*152*	287	*11*	*142*	*139*	130	...
Dover	...	110	...	...	...	313	...	...	...	...	...
Staplehurst	...	104	104	104	147	...	17	...	86	128	...
Maidstone	*44*	114	103	115	...	...	76	114	89	...	...
Chiddingfold	10	103	92	112	131	...	58	94	90	131	149
Cranleigh	14	110	102	101	...	298	58	91	110	...	...
Coneyhurst	59	114	99	101	121	...	79	...	136	...	...
Churt Vicarage	8	105	113	114	133	281	58	107	92	126	170
Purley	7	114	112	112	...	285	61	114	88	...	...
Ditton Hill	8	*121*	113	113	...	291	...	...	94	...	...
Marlborough	*42*	100	114	112	133	...	...	...	100	133	170
D											
Oxford	...	*126*	105	...	...	...	...	...	126	...	...
Harefield	...	104	108	115	...	285	83	102	118	132	160
Chesham	...	101	106	131	...	274	58	92	...	132	...
Watford	...	113	110	117	...	295	58	105	105	...	...
St. Albans (New Farm)	6	106	113	108	133	295	63	93	107	131	193
St. Albans (Glenferrie Road)	6	125	124	124	138	...	58	91	*63*	132	...
King's Langley	...	*132*	125	116	...	...	...	124	126	...	...
Berkhamsted	14	102	106	114	*157*	293	58	91	89	131	164
Harpenden	...	123	109	121	...	...	78	61	108	...	...
Ross	4	110	124	113	*155*	...	48	...	112	...	...
Dymock	26	96	113	128	146	*238*	58	80	114	*105*	...
West Malvern	4	118	*90*	...	...	283	*6*	73	125	127	166

TABLE V.—Date (Day of Year) of Song and Migration of Birds, and First Appearance of Insects, 1907—*continued.*

Station.	Song.	Migration.					Insects.				
	Song-Thrush first heard.	Swallow first seen.	Cuckoo first heard.	Nightingale first heard.	Flycatcher first seen.	Swallow last seen.	Honey Bee.	Wasp.	Small White Butterfly.	Orange Tip Butterfly.	Meadow Brown Butterfly.
Farnborough	1	108	115	127	135	282	17	72	87	152	195
Stone	10	100	115	...	122	307	...	...	...	133	...
Ketton	...	...	*145*	114	...	...	...	...	114	145	...
Beeston	9	96	118	...	...	266	80	90	90	...	...
Hodsock	42	115	125	123	133	305	15	89	96	161	...
Macclesfield	43	132	131	...	...	277	89	91	90	...	...
Belton	6	...	115	115	117	288	40	*204*	146	150	184
Altofts	47	97	...	...	...	...	...	...	...	...	...
Ripley	47	105	*89*	...	136	272	48	...	85	144	...
E											
Broxbourne	4	...	...	*96*	...	320	...	*51*	...	...	...
Hatfield	13	126	112	113	...	...	77	105	114	...	...
Sawbridgeworth	9	103	118	116	131	...	56	80	89	131	...
Hitchin	12	112	114	112	...	...	...	...	...	...	...
Odsey (Ashwell)	...	105	124	116	...	294	...	...	...	...	...
Shelford	...	95	114	118	...	303	...	117	119	133	143
Lexden	8	112	119	109	130	284	59	91	88	126	193
Carleton-Forehoe	18	105	115	121	132	...	52	83	84	128	...
Tacolneston	15	112	116	...	...	...	59	...	...	128	...
Eaton (Norwich)	...	...	125	...	...	...	...	...	...	...	...
Southacre	16	110	125	114	129	291	58	124	134	...	175
Brunstead	13	106	112	...	137	285	56	112	106	147	*209*
Hevingham	*46*	113	120	...	...	...	...	...	...	...	...
Clenchwarton	16	104	125	...	...	...	*8*	...	122	159	...
Peterborough	5	112	112	110	125	331	46	95	93	145	...
F											
Llangollen	40	106	112	...	132	279	84	95	86	132	...
Betley	49	104	113	...	138	291	87	90	113	*171*	201
Preston	8	125	125	...	...	306	15	103	91	...	...
Ambleside	47	113	116	...	129	...	...	...	126	144	205
Cronkbourne	53	123	131	...	...	*259*	39	126	106	148	153
G											
Ardgillan	14	111	114	...	136	269	59	112	106	134	183
Edgeworthstown	...	112	123	...	145	277	...	135	106	126	...
Westport	2	120	125	...	...	...	...	...	...	...	...
Chanter Hill	33	95	127	...	...	272	81	133	117	145	150
Loughbrickland	46	105	116	...	...	277	81	...	113	138	...
Saintfield	15	111	116	...	134	...	82	...	115	135	...
Antrim	15	115	125	...	145	275	73	111	98	126	...
Altnafoyle	49	*128*	130	...	...	...	*134*	145	128	137	199
Milford	14	119	125	...	...	266	77	134	131	139	...
H											
Kirkmaiden	25	104	130	...	...	285	83	124	...	136	...
New Galloway	54	126	126	...	...	...	56	126	...	...	...
Jardington	47	116	125	...	...	274	...	134	116	...	207
Moniaive	...	120	119	...	...	276	...	132	125	...	...
Port Ellen	21	119	128	...	...	...	*21*	...	124	139	...

TABLE V.—Date (Day of Year) of Song and Migration of Birds, and First Appearance of Insects, 1907—*continued.*

Station.	Song.	Migration.					Insects.				
	Song-Thrush first heard.	Swallow first seen.	Cuckoo first heard.	Nightingale first heard.	Flycatcher first seen.	Swallow last seen.	Honey Bee.	Wasp.	Small White Butterfly.	Orange Tip Butterfly.	Meadow Brown Butterfly.
I											
Thirsk	45	116	125	...	133	275	56	114	86	...	...
Durham	57	121	...	...	...	...	69	127	121	...	...
Corbridge-on-Tyne	49	119	127	...	...	271	...	...	...	...	...
West Foulden	...	...	...	...	...	284	...	...	...	...	197
J											
Forgandenny	48	131	132	...	147	...	58	87	149	...	...
Kirriemuir	...	128	136	...	...	274	56	*153*	...	...	...
Durris	20	115	124	...	145	279	56	90	112	169	190
Crathes	17	125	125	...	...	279	...	...	...	*221*	...
Aberdeen	42	128	*166*	...	...	*248*	91	86	...	...	...
K											
Invermoidart	50	...	126	...	...	...	...	101	...	...	...
Beauly	50	133	132	...	161	...	48	146	*201*	...	...
Dingwall	46	126	131	...	152	...	63	132	131	...	...
Inverbroom	57	...	128	...	...	...	61	146	139	...	...
Watten	...	...	*166*	...	...	...	59	...	133	...	203
Mean Dates for the British Isles in 1907	22 Jan. 22	110 Apl. 20	118 Apl. 28	115 Apl. 25	135 May 15	288 Oct. 15	59 Feb. 28	103 Apl. 13	105 Apl. 15	135 May 15	179 June 28
Mean Dates for 1891-1907	Jan. 23	Apl. 17	Apl. 22	Apl. 21	May 15	Oct. 11	Feb. 25	Apl. 12	Apl. 18	May 10	June 12

The dates in *italics* have not been taken into consideration when calculating the means for the British Isles.

later than I had ever heard it in the last 34 years. *Beeston* (D)—5th. Cuckoo still heard with unbroken note. 15th. Strawberries small and lacking flavour. *Hodsock* (D)—Many strawberries rotted on the ground instead of ripening. *Lexden* (E)—10th. Hail-storm sadly damaged many vegetables and flowering plants in the garden. *Southacre* (E)—15th. Heard the cuckoo's cry and even its gurgling note. *Clenchwarton* (E)—Wild rose blossoms still very abundant. *Betley* (F)—25th. Sweet peas remarkably good. *Thirsk* (I)—15th. Hay first cut. *Durris* (I)—8th. Cuckoo last heard.

August. *Altarnon* (A)—2nd. Hay still being harvested. *Mawnan* (A)—16th. Corn harvest began. *Brixham* (A)—Have not seen an orange tip butterfly this summer. *Whitney-on-Wye* (A)—9th. Corn harvest began, while some hay was still out in the fields. *St. Albans* (*New Farm*) (D)—7th. Dog-roses only now out of flower. Wasps and house-flies not so numerous as usual. *St. Albans* (*Glenferrie Road*) (D)—Marked scarcity of butterflies. *King's Langley*

TABLE VI.—Estimated Yield of Farm Crops in 1907.

Description of Crop.	England.						Scotland.			Ireland.	British Isles.
	A S.W.	C S.	D Mid.	E E.	F N.W.	I N.E.	H W.	J E.	K N.	B and G S. and N.	
	%	%	%	%	%	%	%	%	%	%	%
Wheat	+ 4	+ 8	+ 8	+11	+ 3	+ 6	- 3	0	+23	+ 3	+ 7
Barley	- 1	+ 5	+10	+ 9	- 5	+ 2	- 4	- 3	0	0	+ 6
Oats	+ 7	+13	+17	+12	+ 6	+ 8	- 5	+ 2	+ 1	0	+ 6
Corn Harvest began, average Date, day of Year	232	226	234	229	241	241	...	...	...	...	234
Beans	0	+16	+15	+17	+10	+ 6	+ 3	+ 1	-19	+10	+14
Peas	0	+12	+ 5	+10	+ 2	- 5	- 8	+ 2	+20	+ 8	+ 8
Potatoes	-29	- 7	- 4	+ 6	-27	-12	-13	- 9	-17	- 8	- 7
Turnips	+ 3	+19	+15	+11	- 1	+ 3	-29	- 6	+19	- 5	+ 5
Mangolds	+ 5	+ 7	+ 3	+10	- 1	0	-28	- 6	+15	+ 2	+ 3
Hay (Permanent Pastures)	+ 8	+14	+15	+ 7	+10	+11	- 2	+ 9	+18	0	+ 6
Hay (Clover, etc.)	+ 5	+17	+15	+ 9	+12	+15	+ 2	+ 9	+12	-17	+ 7

Symbols:—+ = Over. - = Under. 0 = Average.

The variations from the average in the above-mentioned crops have been obtained from the *Agricultural Returns*, 1907 (*Produce of Crops*), issued by the Board of Agriculture, while the average dates of the Harvest have been derived from returns which appeared in the *Agricultural Gazette*, July 29 to August 26, 1907.

TABLE VII.—Estimated Yield of Fruit Crops in 1907.

Description of Crop.	England.						Scotland.	Ireland.	British Isles.
	A S.W.	C S.	D Mid.	E E.	F N.W.	I N.E.	H, J, and K W. E. and N.	B and G S. and N.	
Apples	-	-	-	-	-	-	-	-	-
Pears	-	-	-	-	-	-	-	-	-
Plums	0	+	+	+	-	+	-	-	+
Raspberries	+	+	+	+	+	+	+	+	+
Currants	+	+	+	+	+	+	+	+	+
Gooseberries	+	+	+	+	+	+	+	+	+
Strawberries	0	0	-	-	-	-	+	0	-

Symbols:—+ = Over. - = Under. 0 = Average. This Table has been compiled from returns which appeared in the *Gardeners' Chronicle*, August 3, 1907.

TABLE VIII.—Variations from the Average in Mean Temperature, Rainfall, and Sunshine, 1906-7.

Winter 1906-7.

Temperature.

Months.	Eng. S.W.	Ire. S.	Eng. S.	Eng. Mid.	Eng. E.	Eng. N.W.	Ire. N.	Scot. W.	Eng. N.E.	Scot. E.	Scot. N.
	°	°	°	°	°	°	°	°	°	°	°
December .	−1·2	−0·4	−1·9	−1·1	−2·3	−1·0	+0·2	−0·9	−1·3	−0·1	−0·6
January . .	−2·0	−0·4	−1·2	−0·9	−1·0	−1·0	+0·3	−0·6	−1·4	−1·0	−0·7
February . .	−2·4	−0·9	−1·9	−0·9	−1·1	−1·3	−0·8	−0·8	−0·4	−0·2	−0·5
Winter . .	−1·9	−0·6	−1·7	−1·0	−1·5	−1·1	−0·1	−0·8	−1·0	−0·4	−0·6
					Rain.						
	in.	in.	in.	in.	in.	in.	in.	in.	in.	in.	in.
December .	−0·9	−1·4	−0·8	−0·1	+0·1	+0·3	0·0	−0·4	+0·1	+0·5	0·0
January . .	−1·7	−2·8	−1·3	−1·3	−0·6	−1·4	−1·3	−1·8	−1·0	−1·1	+0·3
February . .	−0·6	−1·0	−0·5	−0·4	−0·2	0·0	−0·1	+0·3	−0·1	−0·1	+1·8
Winter . .	−3·2	−5·2	−2·6	−1·8	−0·7	−1·1	−1·4	−1·9	−1·0	−1·7	+2·1
					Sunshine.						
	hrs.	hrs.	hrs.	hrs.	hrs.	hrs.	hrs.	hrs.	hrs.	hrs.	hrs.
December .	+ 6	− 6	+11	+12	+ 8	+10	0	+ 3	+11	+ 3	−11
January . .	+13	−16	+16	+17	+17	+14	− 9	− 8	+34	+ 8	− 8
February . .	− 1	+ 6	+10	+17	− 3	+21	+ 8	+18	+30	+31	+ 9
Winter . .	+18	−16	+37	+46	+22	+45	− 1	+13	+75	+42	−10

Spring 1907.

Temperature.

	°	°	°	°	°	°	°	°	°	°	°
March . .	+1·1	+2·8	+1·2	+2·0	+1·3	+1·9	+2·3	+1·8	+2·1	+1·9	+1·5
April . .	−0·9	−0·9	−0·3	+0·3	+0·7	−0·2	−0·6	0·0	+1·0	0·0	+0·5
May . .	−1·5	−1·9	−1·1	−1·1	−0·2	−1·4	−1·8	−1·5	−0·6	−2·5	−1·2
Spring . .	−0·4	0·0	−0·1	+0·4	+0·6	+0·1	0·0	+0·1	+0·8	−0·2	+0·3
					Rain.						
	in.	in.	in.	in.	in.	in.	in.	in.	in.	in.	in.
March . .	−1·0	−0·7	−0·8	−0·5	−0·4	+0·7	+1·6	+0·8	−0·6	−0·2	+1·5
April . .	+1·7	+0·4	+1·5	+0·3	+0·4	−0·6	+0·1	+0·2	0·0	+0·1	−0·1
May . .	+0·8	+1·0	+0·6	+1·3	+1·1	+0·8	+1·9	+1·8	+2·0	+1·2	+0·7
Spring . .	+1·5	+0·7	+1·3	+1·1	+1·1	+0·9	+3·6	+2·8	+1·4	+1·1	+2·1
					Sunshine.						
	hrs.	hrs.	hrs.	hrs.	hrs.	hrs.	hrs.	hrs.	hrs.	hrs.	hrs.
March . .	+36	+16	+77	+60	+75	+59	+24	+77	+80	+45	+10
April . .	− 7	−20	+10	−10	− 7	+ 3	−20	−10	+12	+14	+11
May . .	−70	−31	−53	−60	−33	−70	−35	−47	−45	−72	−26
Spring . .	−41	−35	+34	−10	+35	− 8	−31	+20	+47	−13	− 5

+ indicates above the average, − below it.

TABLE VIII.—VARIATIONS FROM THE AVERAGE—*continued.*

SUMMER 1907.

Temperature.

MONTHS.	Eng. S.W.	Ire. S.	Eng. S.	Eng. Mid.	Eng. E.	Eng. N.W.	Ire. N.	Scot. W.	Eng. N.E.	Scot. E.	Scot. N.
	°	°	°	°	°	°	°	°	°	°	°
June . .	−3·6	−3·1	−2·7	−3·0	−1·1	−3·2	−3·8	−3·4	−1·1	−3·3	−2·6
July . .	−2·3	−0·3	−3·6	−3·4	−3·7	−2·3	−1·0	−0·6	−3·2	−3·3	−1·6
August . .	−0·9	−0·6	−1·1	−0·8	+0·1	−1·5	−1·6	−1·6	−0·2	−2·5	−2·4
Summer . .	−2·3	−1·3	−2·5	−2·4	−1·6	−2·3	−2·1	−1·9	−1·5	−3·0	−2·2
					Rain.						
	in.	in.	in.	in.	in.	in.	in.	in.	in.	in.	in.
June . .	+1·4	+1·1	0·0	+0·4	−0·3	+2·8	+2·0	+2·3	+0·8	+1·3	+2·0
July . .	+0·2	+0·2	−0·7	+0·9	−0·7	−0·6	−0·4	−1·1	−1·4	−0·5	−1·2
August . .	−0·7	−1·2	−0·6	−0·7	−1·1	+0·2	−0·4	+1·0	−0·6	+0·3	+2·0
Summer . .	+0·9	+0·1	−1·3	+0·6	−2·1	+2·4	+1·2	+2·2	−1·2	+1·1	+2·8
					Sunshine.						
	hrs.	hrs.	hrs.	hrs.	hrs.	hrs.	hrs.	hrs.	hrs.	hrs.	hrs.
June . .	−77	−56	−33	−30	−40	−63	−47	−78	−11	−37	−44
July . .	+7	+30	−15	−26	−30	−2	+30	+8	−18	−45	−4
August . .	−34	−14	−3	0	−11	−9	+8	−3	+21	−9	−16
Summer . .	−104	−40	−51	−56	−81	−74	−9	−73	−8	−91	−64

AUTUMN 1907.

Temperature.

	°	°	°	°	°	°	°	°	°	°	°
September .	+1·6	+2·8	+1·2	+1·3	+1·1	+1·7	+1·8	+1·2	+1·2	+0·7	+0·7
October . .	+0·4	+0·4	+2·2	+1·8	+3·2	+1·0	+1·3	+1·4	+2·1	+1·3	+1·4
November .	0·0	−1·4	+1·3	+0·9	+2·0	−0·2	−0·3	−0·9	+0·4	+0·2	0·0
Autumn . .	+0·7	+0·6	+1·6	+1·3	+2·1	+0·8	+0·9	+0·6	+1·2	+0·7	+0·7
					Rain.						
	in.	in.	in.	in.	in.	in.	in.	in.	in.	in.	in.
September .	−1·6	−1·1	−1·5	−1·2	−1·5	−2·1	−1·5	−2·6	−1·3	−1·0	−1·8
October . .	+2·5	+2·0	+2·2	+2·3	−0·3	+0·8	+0·3	+0·8	+1·5	+2·4	−2·8
November .	−0·5	−0·4	−0·4	+0·1	+0·1	−0·2	−0·7	−0·6	−0·2	−0·7	−0·4
Autumn . .	+0·4	+0·5	+0·3	+1·2	−1·7	−1·5	−1·9	−2·4	0·0	+0·7	−5·0
					Sunshine.						
	hrs.	hrs.	hrs.	hrs.	hrs.	hrs.	hrs.	hrs.	hrs.	hrs.	hrs.
September .	+23	−15	+34	+28	+41	+20	−15	+9	+54	+51	+29
October . .	−12	−34	−16	−5	−14	+4	−21	−23	+5	−14	+5
November .	+4	+9	−1	+6	−8	+5	+21	+8	+9	+14	+11
Autumn . .	+15	−40	+17	+29	+19	+29	−15	−6	+68	+51	+45

The above Table has been compiled from the variations from the mean given in the *Weekly Weather Reports* issued by the Meteorological Office.

TABLE IX.—Supplementary Observations in 1907.

BIRDS.

Chiff-Chaff (first heard).

Station.	District.	Date.
Mawnan	A	April 1.
Bagenalstown	B	March 24.
Ovoca	B	,, 26.
Ardgillan	G	,, 27.
Edgeworthstown	G	,, 28.

Corncrake (first heard).

Station.	District.	Date.
Bridgend	A	May 8.
Whitney-on-Wye	A	,, 17.
Ovoca	B	,, 7.
Ripley	D	,, 13.
Cronkbourne	F	,, 10.
Chanter Hill	G	April 22.
Altnafoyle	G	,, 30.
Tardington	H	May 29.
Moniaive	H	,, 8.
Thirsk	I	,, 10.
Corbridge-on-Tyne	I	April 23.
Durris	J	May 11.

Swift (first seen).

Station.	District.	Date.
Brixham	A	May 10.
Bridgend	A	,, 5.
Ovoca	B	,, 5.
Cranleigh	C	,, 18.
Churt Vicarage	C	,, 5.
Harefield	D	,, 24.
Dymock	D	,, 6.
Ripley	D	,, 5.
Odsey	E	,, 14.
Altnafoyle	G	,, 12.
Corbridge-on-Tyne	I	,, 18.
Durris	J	,, 19.

PLANTS.

Winter Aconite.

Whitney-on-Wye	A	Feb. 18.
Cambridge	C	Jan. 16.
Churt Vicarage	C	,, 17.
Watford	D	,, 8.
Berkhamsted	D	Feb. 11.
Clenchwarton	E	Jan. 7.

(D)—Oats were first cut on the 2nd, and wheat on the 9th. *Harefield* (D)—5th. Oats first cut. 11th. Swift last seen. 29th. Wheat first cut. *Farnborough* (D)—Scarcely any butterflies all the summer. *Northampton* (D)—Some hay not carried before the middle of the month. *Hodsock* (D)—10th. Hay harvest finished. 16th. Oats cut. *Ripley* (D)—27th. Swift last seen. *Odsey* (*Ashwell*) (E)—15th. Wheat cut. 21st. Barley cut. 30th. Oats cut. *Bocking* (E)—16th. Harvest began. *Lexden* (E)—The usual autumn butterflies almost non-existent here, but wasps were extremely numerous. *Clenchwarton* (E)—19th. Very few wasps. 30th. Leaves of wych elm turning colour. *Llangollen* (F)—Hay harvested in fair condition. *Cronkbourne* (F)—27th. Harvest began. *Antrim* (G)—Very few butterflies, wasps, or house-flies. 20th. Swift last seen. 22nd. A brood of swallows left their nest. *Thirsk* (I)—14th. Hay harvest completed. 28th. First corn cut. *Beauly* (K)—Much hay harvested in good order during the third week.

September.—*Altarnon* (A)—The straw of corn crops heavy everywhere. *Whitney-on-Wye* (A)—Potatoes much diseased. Blackberries a failure. *Ovoca* (B)—On the whole a very poor harvest. Very few wasps and not many butterflies. *Churt Vicarage* (C)—10th. The early autumn flowers particularly full of bloom. 23rd. Dahlias and French beans destroyed by frost in lower parts of the parish. *Ditton Hill* (C)—All fruits this year are wanting in flavour. Potatoes considerably diseased. *Farnborough* (D)—1st. An abnormal number of earwigs. *Beeston* (D)—Very few butterflies, but plenty of earwigs. *Hodsock* (D)—6th. Enormous crops of plums. 24th. Corn harvest finished. *Macclesfield* (D)—Gardens looked brighter and the flowers were more abundant at the end of the month than at any time in the year. *Bocking* (E)—24th. Harvest

finished. *Southacre* (E)—19th. Harvest finished. *Clenchwarton* (E)—27th. Harvest finished. *Llangollen* (F)—Splendid weather for early harvests. *Betley* (F)—13th. Oats carried. *Cronkbourne* (F)—4th. Dahlias slightly blackened by frost. *Moniaive* (H)—3rd. Potatoes, holly, bay, phlox, etc., blackened by frost. *Thirsk* (I)—4th. Marrows and kidney beans killed by frost. *Aberdeen* (I)—Two or three weeks in this month the only genial ones in the whole year.

OCTOBER.—*Altarnon* (A)—31st. Second crop of grass very good. *Whitney-on-Wye* (A)—16th. Dahlias and beans blackened by frost. *Bagenalstown* (B)—23rd. Gathered a dish of peas. *Churt Vicarage* (C)—25th. My dahlias were destroyed by frost. *Harefield* (D)—20th. Martin last seen. *Dymock* (D)—8th. Dahlias blackened by frost. *Hodsock* (D)—8th. Peas have very little flavour. 13th. A large crop of apples. 21st. Gathered a dish of peas. *Clenchwarton* (E)—16th. A nest of young swallows ready to fly. 20th. Blackberries plentiful, but small and still green. *Llangollen* (F)—Weather bad for late harvests and working the land. *Saintfield* (G)—31st. Much corn still in the fields. *Thirsk* (I)—21st. Quite half of the corn in this district still out in the fields and some not cut.

NOVEMBER.—*Altarnon* (A)—Very late defoliation of many trees. *Tiverton* (A)—32 wild flowers and 63 garden flowers were in blossom during the month. 1st. A large peach gathered out of doors. 6th. Half a pint of blackberries gathered. *Aberystwith* (A)—21st. Dahlias killed. *Whitney-on-Wye* (A)—Many leaves still on the trees at the end of the month. *Churt Vicarage* (C)—15th. Autumn tints not so bright as usual. *St Albans* (*New Farm*) (D)—Geraniums and heliotropes in flower until the 22nd. All the deciduous trees kept their foliage later than usual. *St Albans* (*Glenferrie Road*) (D)—Holly-trees laden with berries. *Berkhamsted* (D)—16th. Dahlias killed by frost, 10 days later than the average date of their destruction in the previous 22 years. *Farnborough* (D)—*Daphne mezereon* in bloom. *Hodsock* (D)—5th. Autumn tints showing a little, but never really good. *Odsey* (E)—1st. Common elms in full leaf. 5th. Half of the foliage yellow. 9th. Have lost but few leaves. 19th. In exposed places they retain but a sprinkling of their leaves. 30th. Still a few leaves on the common elm. Other trees virtually bare. *Clenchwarton* (E)—30th. Roses still in bloom. *Llangollen* (F)—Corn still unharvested on upland farms. *Betley* (F)—6th. Never saw flowers in the garden in such profusion so late in the year. *Thirsk* (I)—10th. Harvest not yet completed on upland farms. *Durris* (I)—Unprecedented length of harvest. *Aberdeen* (J)—Much harvest work had to be done this month. *Beauly* (K)—Last corn secured in fair condition by the middle of the month.

DISCUSSION.

Mr. R. H. HOOKER congratulated Mr. Mawley on his Report. These papers were always very interesting, and Mr. Mawley's summary of the whole season was admirable. He wished to call attention to one point, and that was the apparent failure of Dr. Shaw's relationship between the autumn rainfall and the wheat supply. This failure was only apparent. Fifteen months ago, he (Mr. Hooker) had gone thoroughly into the question. He had taken Dr. Shaw's point and extended it over other crops and weather at different parts of the year. The result had confirmed Dr. Shaw's opinion. In the autumn of 1906 the rainfall was above the average, but not very much, and he had come to the conclusion that the probable deficiency of the wheat yield due thereto was about 1 bushel per acre. There were, however, two abnormal seasons affecting the harvest of 1907, viz.: the cool spring and summer, and the hot summer of

the preceding year. Each of these probably accounted for an increase of 2-3 bushels, against which had to be set the deficiency due to the wet autumn, leaving something like 4-5 bushels per acre above the average as the effect of the whole period. The chief feature of the year had been the very cool spring and summer, which he thought conduced to bulk in nearly all crops. The beautiful summer of 1906 had also had a good influence upon the grain seeds, and these two factors accounted for the very great abundance of nearly all crops in 1907.

Mr. F. C. BAYARD said he had listened with great interest to Mr. Mawley's report. In 1891 Mr. Mawley had taken a mean of the previous 8 years, and after that he commenced taking the means from 1891 up to the present time. He (Mr. Bayard) considered it might be an advantage if the mean of the first 8 years were added to the mean for 1891 to 1907. They would get an average of 25 years. Mr. Mawley had mentioned that wasps were a day late; they were very scarce during the summer, but in September they were very great in number.

Mr. H. MELLISH remarked that he would like to know whether Mr. Mawley had received any reports upon the extraordinary number of small flies in the early autumn of last year. As regards the large produce of so many crops last year, in many of the late districts these were scarcely harvested at all. He himself had watched one field of wheat which was only harvested just before Christmas. In the North things were still worse. The total yield might have been very good, but a great deal of the harvest must have been got in in a bad condition. The value of the produce was only calculated on the price of the best samples.

Mr. W. W. BRYANT remarked that at the Royal Observatory, Greenwich, he had noticed a magnolia flowering twice, the second time fairly late in the year. He had not known this to happen before.

Mr. C. HARDING said he hoped Mr. Mawley would stay his hand in the execution of one threat, and that was when he said that he would delete the early years of the diagram which he showed for 17 years for different districts. Rather than cut out any of the years he would suggest that Mr. Mawley might make five-yearly averages of them. He thought the great value of these observations lay in the long period over which they extended.

Mr. J. E. CLARK said he had heard that the honey crop was a failure, probably because it depended entirely upon the weather of the months which were so specially cool, May to July. He thought one reason of the reports of ruin was because the farmers, like others, were apt to cry out when things went wrong, but kept quiet when everything was going right. The after effects of the season were also interesting, as shown in the condition of the flowering plants at the end of the season. Last year there had been practically no frost, and very little of the flowering plants had therefore been destroyed. He had taken observations of the number of flowering plants in his garden, and there had not been so much difference as might have been anticipated between 1906 and 1907, though the latter year showed greater profusion. Mr. Clark then gave some comparative figures concerning plants, remarking that last year he had at Christmas 50 garden and 45 wild plants. Many roses in December were still in bloom. The totals for January of last year had come out more than for this year, being 23 this year and 26 plants last year. The frost in February had reduced the number still more.

Mr. E. MAWLEY in reply said he was much interested in the remarks made by Mr. Hooker upon the probable effect of the different seasons upon agricultural produce. He was, however, still of opinion that Dr. Shaw's theory had not been last year borne out by the results of the harvest. Dr. Shaw's theory, as originally stated, was that the yield of wheat in one year was in

inverse proportion to the quantity of rain deposited during the previous autumn. Whereas the yield of wheat in 1907, and also the rainfall of the autumn of 1906, were throughout the corn-growing districts of England in excess of the average. In answer to Mr. Bayard he need only say that previous to 1891 the observations of the 13 plants were in no district sufficiently numerous to be of any service in a comparative table like Table I.

Mr. R. H. HOOKER said that Mr. Mawley had apparently misunderstood his remarks about Dr. Shaw's calculations. The autumn period of the year had been swamped by other periods which happened in 1907 to be of more importance.

The Climate of Davos.

We have received from Dr. Hugo Bach a pamphlet on this subject, which forms Bd. xlii. 1 of the *Neue Denkschriften der Schweizerischen Naturforschenden Gesellschaft.* The paper is based upon the material furnished by the Meteorological Station at Davos, and, in addition to its tables, curves, and summaries contains a discussion on the hygienic aspects of the Davos climate. Of the general points which emerge from the investigation, the most important is the emphasis which the author lays upon the distinction to be drawn between the climate of an elevated valley and that of a mountain summit. As is well known, a mountain climate tends to approach the insular type, but the Davos observations show that the elevated valley climate approaches nearer the continental type. As regards the different climatic elements, the pressure, as it is to be expected from the elevation, is low, and the variations relatively small. As in other elevated regions, the maximum falls in the summer, not in the colder months as at lower levels. The valley is sheltered from the wind, and calms are frequent. The amount of cloud reaches its minimum in winter, and is small as compared with towns in the plain, *e.g.* Zürich, and with mountain summits, like the Rigi-kulm. The low pressure results in a low humidity of the air; in winter, especially, the difference between the amount of atmospheric moisture in the Davos valley and in the low ground is enormous. As a result again of this, and also of the broad shape of the valley, and of the reflecting snow mountains around, insolation is very strong. This insolation again gives the climate an extreme and thus a continental character. Not only does it produce a well-marked effect on the summer and winter means, but it also produces marked diurnal variations of temperature in objects exposed to the sun's rays. At the Schatzalp Sanatorium, which is placed about 300 metres [1000 ft.] above the floor of the valley, both the daily and the annual variations are less marked than at Davos, *i.e.* this station approaches nearer the mountain type of climate. On the other hand it is to be noted that severe shade temperatures can be much more readily tolerated here than on lower ground, owing to the stillness of the dry air and its feeble conductivity. The mean annual precipitation is about 910 mm. (36 ins.), that is, not much more than half that of such places as Lucerne and Lugano (1710 mm.) [67 ins.]. The continental character of the precipitation is especially shown in the time of fall, for while the summer is wet, the winter means, and especially the January means, fall far below those of lower stations. Thus the mean January fall at Davos is under 2 ins. (46 mm.).

As regards the physiological effects of the Davos climate, especially on persons in delicate health, the only point which we can mention here is that the evidence seems to show that the active agents do not appear to be exclusively the meteorological elements as usually measured. It is possible that other factors, such as the electrical condition of the air, and its radioactive emanations, intervene to complicate the problem.—*Scottish Geographical Magazine*, August 1908.

Vincent's Cloud Atlas.

M. J. Vincent, the Meteorologist of the Royal Observatory, Brussels, has given in the *Annales* of the Observatory, Tome 20, an "Atlas des Nuages," or Cloud Atlas. This atlas, he states, has been compiled with the object of making public, especially among observers, a knowledge of the classification published in the International Meteorological Committee's Cloud Atlas in 1896. He has, however, expanded this, and added other forms which, although of secondary importance, he considers should be included. Certain species have also been subdivided into several varieties, the greater part of which have, however, already been described by other authors. He gives an account of the form, relative altitude, and, as far as possible, the origin of the condensations of the various forms of cloud.

He divides the clouds into three groups: (1) Lower, (2) Middle, and (3) Upper. He further subdivides these into the following varieties:—

LOWER CLOUDS.

Species.	*Varieties.*	*Species.*	*Varieties.*
Fumulus		Nimbus	Tonitro-nimbus
Cumulus	Fracto-cumulus	Cumulo-nimbus	Fasciculus
	C. simplex	Stratulus	
	C. congestus	Pileus	
	C. compositus	Nimbo-stratus	
	Pallio-cumulus	Strato-cumulus	Pallio-strato-cumulus
	C. humilis		Fracto-strato-cumulus
	C. pendulus	Stratus	Fracto-stratus
Nimbus	Pallio-nimbus		Stratus cumuliformis
	N. cumuliformis		Stratus hiemalis
	Fracto-nimbus		

MIDDLE CLOUDS.

Species.	*Varieties.*	*Species.*	*Varieties.*
Alto-cumulus	A. cu. pulvinatus	Alto-cumulus	A. cu. incertus
	A. cu. frixus		A. cu. margarodes
	A. cu. floccus		A. cu. castellatus
	A. cu. sphericus	Alto-stratus	
	A. cu. granosus	Virgulus	
	A. cu. corrosus	Cirroides	

UPPER CLOUDS.

Species.	*Varieties.*	*Species.*	*Varieties.*
Cirrus	C. filosus	Tracto-cirrus	T.-c. implexus
	C. uncinus		T.-c. floccosus
	C. fascigerus		T.-c. lactosus
	C. implexus	Cirro-stratus	C.-s. fascigerus
	C. confertus		C.-s. implexus
	C. floccosus		C.-s. floccosus
	C. lactosus		C.-s. lactosus
Tracto-cirrus	T.-c. filosus		C.-s. informis
	T.-c. pennatus	Cirro-cumulus	
	T.-c. vertebratus		

M. Vincent gives twenty-eight photographic reproductions of various forms of clouds, which were taken at the Royal Observatory, Uccle, Brussels. These are extremely interesting, and are likely to be of great assistance to observers in identifying many forms of clouds.

UPPER AIR OBSERVATIONS IN EGYPT.

By B. F. E. KEELING, M.A., F.R.A.S.

[Read May 20, 1908.]

The President has invited me to describe to you the lines on which we are conducting the investigation of the upper air in Egypt. In the present paper it is my intention to give a brief account of the methods we are using at present, and of the directions in which we hope, in the near future, to develop the work. In no country in the world can the problems of commercial value which meteorologists have to solve be stated more simply. The whole justification from the practical point of view of a meteorological organisation in Egypt is the hope that in the end some power of forecasting the state of the Nile may be acquired. In Egypt itself there is comparatively little weather at all, and what there is has no influence commercially except along a narrow belt on the Mediterranean coast, but, on the other hand, the whole prosperity of Egypt is wrapped up in the weather of the neighbouring country of Abyssinia. As the summer rainfall is greater or less in Abyssinia, so is the Nile flood, and, in consequence, the area of land cultivated and the general prosperity greater or less. In years in which, following a bad flood, a bad low stage of the river is to be expected, the early spring showers in Abyssinia are also of very great importance.

Unfortunately there is not, nor for some time is there likely to be, a meteorological service in Abyssinia. It is true that some observations have from time to time been made at Adis Ababa, but anything like a systematic study of the climate and weather in Abyssinia is, for the moment, beyond hope. The result is that we have in the main to be content with indirect lines of research. We have but very imperfect information about the Abyssinian rainfall, so we have to consider the effect of that rainfall, the Nile flood, and to study its relationship with the meteorological conditions prevailing in such of the surrounding countries as have meteorological services. Some progress is undoubtedly being made. Thus, Captain Lyons has shown that there is an apparent, but not very consistent, connection between the summer barometric pressure at Cairo and the following Nile flood.

But it is evident that little advance can be made so long as our observations are confined to the surface, and that it is of the utmost importance to acquire a knowledge of the general atmospheric circulation over the whole area surrounding the rainfall area. This is, of course, stating the matter from the purely local point of view, apart from the value of the work in the general international scheme of Upper Air investigation.

A start was made last summer by establishing an aeronautical station at Helwan Observatory. The observatory is situated on the desert plateau to the east of the Nile, about 25 kilometres (15 miles) south of Cairo, and some 6 kilometres (4 miles) from the river. The principal buildings are 100 metres (330 ft.) above the level of the river.

Up to the present two lines of experiment have been taken up. The first, and I think the most important, is the flying of pilot balloons for

the determination of the direction and velocity of the upper currents. The balloons at present in use are india-rubber ones made by M. Paturel, and are filled with hydrogen to a diameter of about 70 centimetres. The hydrogen is prepared from zinc and sulphuric acid, and is washed and dried on its way to the balloon. The balloons are watched by two observers using the very convenient form of theodolite made by Bosch of Strassburg. We are at present using a base-line rather over 3 kilometres (2 miles) in length, one station being on the tower of the Observatory and the other on a hill in the desert.

Theodolite readings are taken simultaneously at intervals of a minute, the watches used being compared before the experiment. The staff at each station consists of one observer to keep the telescope on the balloon and to read the vertical circle with his disengaged eye, a native clerk to read the horizontal circle and to book the readings, and two native chainmen, one to call the time, and the other to hold an umbrella over the theodolite and observer. The theodolite is surrounded by a square wind-screen.

The height of the balloon and the distance away from the point from which it is released are computed for each minute, and are then plotted on special angle paper, which has been lithographed in the printing office of the Survey Department. For convenience of reference, the trajectories thus obtained are reduced on to cards with the aid of a pantagraph.

The observations have only been in progress for a few months, and it is too early yet to enter on a statistical examination of the results, which are published monthly in the *Cairo Scientific Journal*. It may, however, be stated that the observations of the anti-trade winds made by Teisserenc de Bort and Rotch have been confirmed. At Helwan (lat. 30° N.), the anti-trade wind is reached at a height of about 2000 metres (6500 feet) above sea-level. Given favourable atmospheric conditions, the balloons can be followed to a distance of from fifty to seventy kilometres (thirty to forty-four miles), the height to which they are observed depending, of course, on the character of the wind currents. The greatest height so far reached is 16,500 metres (54,000 feet), and it is of importance to note that on this occasion the South-west anti-trade wind was apparently penetrated and a North-west upper-current encountered.

We have also commenced work with kites. On a plateau behind the Observatory two galvanised iron sheds have been built, one to hold the machinery, and the other a number of kites which are kept strained ready for use. The kite-winch was made by Mr. Cook, mechanic to Manchester University, from designs by Mr. W. H. Dines, F.R.S., and Mr. J. E. Petavel, F.R.S. It is driven by a 3½ h.p. Crossley petrol motor. The whole works admirably, and from the start very little trouble has been experienced. The kites and meteorographs have been supplied by Mr. Dines. In kite-flying we are greatly hampered by the very low wind velocities which are usual at the surface, and by the rather common occurrence of calm-belts, which are often met with even when there is a kite-flying breeze on the ground.

Observations on the air currents in Central Africa during the rainy season are much needed, and it has been arranged for me to spend the month of August at Mongalla (latitude 5° N.). I am taking up with me apparatus for work with both pilot balloons and kites, though it is

unlikely that there will be more than two or three days on which we shall be able to use the latter, as the winds are as a rule exceedingly light. On my return in September I shall probably make a few days' observations at Port Sudan on the Red Sea coast.

I hope that during next winter our investigations may be considerably developed. It is intended, in the first place, to examine in greater detail the direction and velocity of the wind in the lower strata of the atmosphere to a depth of 2000 or 3000 metres (6500 or 10,000 feet). In Egypt surface winds are usually very light, and are greatly influenced by very local circumstances.

We frequently find that observations of the wind at the surface are no guide to the nature of the wind at an altitude of only 100 or 200 metres (330 or 650 feet). A striking example of this was furnished by two pilot balloon flights made last December at Aswan. Here a North wind is recorded on almost every day in the year. On the days of observation this North wind was found to be only 200 metres (650 feet) thick, being succeeded by a due East wind.

For this study of the lower strata it is proposed to send up small pilot balloons daily, using a short base of 500 metres (1650 feet). The long distance balloon flights will be continued five or six times monthly I hope that it may also be possible to occasionally send up balloons at Alexandria and at Aswan, where the interesting ascents in December would appear to justify systematic observations being made. The smallness of our staff will, however, be a difficulty, and I hope that any British meteorologist wishing to spend a winter abroad will come and make upper air observations at Aswan.

I hope also that the research into the temperature and humidity gradients may be extended, but here, as I have remarked before, there are considerable difficulties in front of us owing to low wind velocities. We may perhaps be able to improve matters by changing our form of kite, and perhaps by having 1000 or 2000 metres (3300 or 6500 feet) of lighter wire for the first kite. In Europe and America the use of ballons sondes has greatly extended the information about the temperature gradient. In Egypt, however, owing to the peculiar geographical conditions it does not seem possible to make use of them to the best advantage. If a balloon were sent up at Helwan the instruments would invariably fall many miles in the desert, and the chances of recovery would be infinitesimal. If ascents were made in the Delta, although some percentage of the balloons would burst above the cultivated area, it is exceedingly doubtful whether more than a very few of these would be returned. I think for the present we shall have to limit our ambitions to the first 5000 or 6000 metres (16,000 or 20,000 feet), sending up instruments attached to balloons, and fitting some form of time-fuse, so that after twenty or thirty minutes the instruments would be released. A small balloon would be attached to and fall with the instruments, and would act as a signal flag to facilitate recovery.

DISCUSSION.

Mr. C. J. P. Cave said that he congratulated Mr. Keeling heartily on the work he had done in Egypt. It was a very interesting place on account of the

clearness of the air. With regard to the high ascent referred to by Mr. Keeling it was probable that the balloon went through the South-west anti-trade into the isothermal zone. Very few observations had been made of the drift of balloons in the isothermal zone, and he hoped that Mr. Keeling would be able to repeat observations at this height. Mr. Cave said that he noticed on some of the diagrams that the wind backed with increasing height; in this country it usually veers at first. He was interested to notice the decrease in velocity which occurred between winds from different directions; he had noticed the same phenomenon in this country. He wished to ask whether the vertical velocity varied much; he himself had found that the vertical velocity was variable when the balloon was in a bad position with regard to the base line, in other words the apparent departures from a uniform ascensional velocity were mainly due to errors of observation.

Dr. W. N. SHAW said that observations of the upper air were a very attractive subject, and Mr. Keeling's presentation of the subject both in his paper and diagrams was excellent. He hoped Mr. Keeling, however, would not write off the surface winds as bad debts; they were extraordinarily annoying, but there must be something in them. It would be a great pity if they were disregarded as not being worth following. As soon as they could get a real working formula between the actual wind at some level and the pressure gradient at the same level, they would afford an interesting field for study and investigation. He hoped, therefore, that Mr. Keeling would lose no opportunity of pursuing these surface winds as far as possible. A point of great interest about the results was, that although very frequently the upper air current set from the west or south-west, there were occasions when it set from the north; that must be a circumstance interesting to Egypt and other parts of the world meteorologically connected with Egypt. He could not account for the northerly set of the wind in the upper air over Egypt; before attempting an explanation it would be necessary to know the set of the upper air at other places.

Colonel H. E. RAWSON remarked that he would ask Mr. Keeling to bear in mind, when he went down south in August and September, that he would be dealing with a region in which the equatorial belt was over him. When he came a little further north, he would leave that belt and get into the edge of the northern anticyclonic belt, where the conditions of the upper air were different. These changes of wind appealed to two sections of his audience, and were very interesting to those like himself who wished to know more about the lower surface winds, and to those who were less interested in the surface than in the upper currents. It was important to know what was going on in Egypt when the change took place from the anticyclonic to the equatorial belt and *vice versa*, and he welcomed this contribution.

Mr. E. S. BRUCE said that he thought it might be desirable to try some lighter forms of kites in Egypt. Some very creditable ascents had been made with light ones. The ordinary box-kite was perhaps unsurpassed in a stiff breeze, but on days when there was not enough wind for it, lighter forms of kites had been flown successfully. Mr. Salmon's eighteen-wing kite appeared to be a good form for light winds, and at the kite display last summer had reached an altitude of about 3000 feet, though the wind was very light.

Mr. B. F. E. KEELING, in reply, thanked the Fellows for the way in which they had received his paper, and also those who had spoken, showing that work was being done which proved of interest to meteorologists. He wished it were possible to tackle the whole question of surface winds, but they could devote very little time to this work, which could only be done in the slack season in Egypt. However, they were making a definite start in the question. With regard to Mr. Cave's question, he found in the lower strata that the wind had

a tendency to veer, but it backed as it went into the upper air, 2000 to 3000 metres above. First there was a veering, and then a backing. As to the changes of vertical velocity, he entirely agreed.

THE PRESIDENT, Dr H. R. MILL, expressed the thanks of the Society to Mr. Keeling for his most able exposition of his extremely interesting and capably carried out investigations on the upper air. It was the beginning of experiments in the branch of meteorology which at present occupied the chief place in the development of the science. Judging from the activity of all parts of the Survey Department, it would almost seem that Egypt would once more become the scientific centre of the world, as it was thousands of years ago.

Tree set on Fire by Lightning.

A wych-elm was struck during a recent thunderstorm in Morhanger Park, near Sandy, Beds. It was set on fire, and smouldered for about a fortnight, when it was cut down. On being opened the centre of the trunk was found to have been converted into charcoal and at the bottom of the burnt part, where a sort of pocket had been formed, was found a greyish-white ball about six inches or so in diameter. On cooling it broke easily. It was naturally supposed to be a thunderbolt, but the lady of the house told me she was sure there were no such things. She was, however, very much puzzled as to what it could be, and so was I; so I had a piece analysed and found it consisted of calcium carbonate with traces of magnesium and iron. It was therefore obviously a product of the tree and not of the lightning, and would be formed by the wood being consumed in what was practically a crucible or retort.

The fire was confined to the interior of the trunk, and there were no marks of damage on the exterior. It is rather a rare thing for a tree to be set on fire by lightning, but I have come across several cases, and in each have found that the injury has been confined to the interior in this way. It is rather remarkable that a growing and healthy tree should be set on fire, and I do not see how it can be accounted for. A highly resisted discharge is more likely to cause fire than one given a fairly easy path, but we should not expect one tree to be so very much more highly resisting than another.

A discharge often keeps to the bark, when there is generally only a groove cut in it, and the tree may not be killed; or if it goes through the body of the tree, the sap is turned into steam and the tree is split to pieces by the explosive effect. In the Morhanger case there appears to have been no explosive effect, yet heat enough to cause fire.

I recently came across a case in which the bark of a tree had been almost entirely torn off, only a narrow strip being left, and this was loose, merely holding by a few fibres. The trunk was left white, and resembled a banana with the peel turned back. This is the first instance of the kind that I have seen.

At the house where I was stopping last week-end in Suffolk, I was shown two thunderbolts (!) that had been found when digging a well. The only reason for supposing them to be thunderbolts was that no other explanation was available. I was unable to say what they were. They appeared to be parts of hollow burnt clay balls very roughly fashioned, and may have been first attempts of some of our ancestors to make earthenware vessels. Perhaps this guess may be as wild as the one that attributed them to lightning.—ALFRED HANDS, 91 Leadenhall Street, E.C., *September* 11, 1908.

Meteorological Investigation in Africa.

According to a message from Rome, Professor Palazzo, Director of the Central Italian Bureau of Meteorology, was to start early in July for Zanzibar

in order to take part in an international scheme for the study of the monsoon winds on the coasts and in the interior of East Africa. At Zanzibar the professor will embark on the torpedo cruiser *Caprera*, from which he will make a series of meteorological studies, partly by means of balloon ascents along the coast.

Simultaneously, British, French, and German expeditions will proceed to the sub-tropical zone of the interior to engage in similar operations there. The most important of these expeditions is undoubtedly the German, which has been organised under the immediate patronage of the Emperor William, His Majesty contributing 50,000 marks (£2500) for the purpose of meteorological research on the Victoria Nyanza; and Professor Palazzo's mission on the coast will be especially connected with the work of this party.—*Scottish Geographical Magazine*, August 1908.

The Climate and Vegetation of Panama.

In *Science* for March 27 an abstract is given of a paper by Dr. R. E. B. M'Kenney on this subject. The differences between the Atlantic and Pacific sides of the Republic are very striking. On the Atlantic side there is no distinct dry season, though less rain falls in February and March than in the later months of the year. In the months of our winter the average temperature varies from 88° to 92° or 93°, and in our summer from 92° to 95°, the minimum temperatures being 60° and 65° respectively. In the Pacific province of Chiriqui, separated from the Atlantic side by the mountain backbone, the temperature range is about the same, but there is a very distinct dry season which lasts five or six months, and during which the vegetation becomes parched and dry. On the Atlantic side, notably at Bocas del Toro, the region studied, the vegetation is luxuriant, with almost impenetrable jungles, mangrove swamps along the sea-coast, and thickets of giant stemless palms. Further inland are forests of palms and exogenous trees, overgrown with aroids and other climbers. On the Pacific side, on the other hand, there are stretches of grass and sharply outlined patches of shrubs, agaves, and species of cactus. At Bocas del Toro bananas are now very extensively cultivated.—*Scottish Geographical Magazine*, August 1908.

Heavy Rainfall in Japan.

In the April number of the *Journal of the Meteorological Society of Japan* an account is given of a very heavy rainfall that occurred in August 1907, and continued for 3 to 7 days in different parts of Japan, and caused a great amount of damage. According to the reports, the regions which had the heaviest rainfall were:—

Western Japan—

Tamba and Tango regions: 13·31 ins. in 1 day, and 20·95 ins. in 2 days.
Eastern part of Kii Peninsula: 13·03 ins. in 1 day; 17·64 ins. in 2 days; and 20·71 ins. in 3 days.
Eastern part of Awa: 8·86 ins. in 1 day, and 13·86 ins. in 2 days.

Eastern Japan—

Western part of Suruga: 14·37 ins. in 1 day, and 23·86 ins. in 2 days.
Central part of Izu: 19·02 ins. in 1 day; 30·01 ins. in 2 days; and 39·92 ins. in 4 days.
Western part of Musashi: 16·34 ins. in 1 day; 26·10 ins. in 2 days; 30·43 ins. in 3 days; and 35·71 ins. in 5 days.
Vicinity of Nikko and Ashio: 7·32 ins. in 1 day; 12·40 ins. in 2 days; and 15·51 ins. in 3 days.

BALLOON EXPERIMENTS IN BARBADOS, NOVEMBER 6-8, 1907.

Communicated by
PROFESSOR J. P. D'ALBUQUERQUE, M.A.

[Read May 20, 1908].

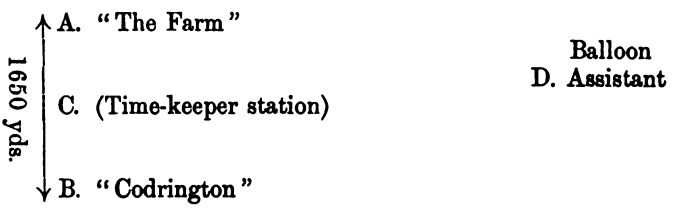
[Sir Daniel Morris, Commissioner of Agriculture for the West Indies, who, at the suggestion of Mr. C. J. P. Cave, kindly undertook to arrange for some balloon experiments to be carried out at Barbados on behalf of the Kite Committee, has forwarded the following Report on the observations made from November 6-8, 1907.—EDITORS].

ONE dozen small balloons and a cylinder of hydrogen were received from the Secretary of the Royal Meteorological Society, with instructions to inflate the balloons with hydrogen and observe their ascent with two theodolites. No further instructions were received, and no one was available with any actual experience of such balloon work. The following course was pursued:—

A Committee, consisting of Mr. J. R. Bovell, F.L.S., Superintendent Botanic Station, and Meteorological observer to the Government of Barbados, Mr. Geo. Lingwood, M.Inst.C.E., Engineer Water-Works Department, Mr. E. F. S. Bowen, M.Inst.C.E., Superintendent of Public Works, and Professor J. P. d'Albuquerque, M.A., Government Chemist, carried out the work, with the help of assistants in their departments.

To ascertain a suitable inflation size for the balloons, a balloon was inflated until it burst, and the circumference, 45 inches, noted. The balloons used in the observed ascents were inflated to a circumference of 35 inches to allow for expansion on ascent.

Three or four balloons were expended in preliminary experiments, and as a result on November 6, two stations were chosen (A) at Codrington and (B) at The Farm, a distance of 1650 yards apart. Each theodolite was worked by three observers, one for the telescope and one for each vernier. By this means it was hoped that the telescope could be kept by one observer constantly on the balloon, while the other two could make "instantaneous" and simultaneous readings at each signal received from the time-keeper, without clamping the telescope. To each theodolite was also attached an attendant to receive the signals. A time-keeper and signaller were stationed at (C) between (A) and (B). The balloon assistant with a signalling attendant took up a point about 2 miles to the north-east of (A) and (B).



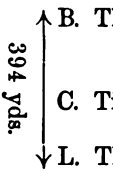
After ascertaining by pre-arranged signals that all the stations were visible one to the other, the balloon was released on a signal from the time-keeper, and half-minute (or in one instance, minute) signals were sent to the theodolite stations until the balloon was out of sight of the time-keeper.

TABLE I.—Balloon Experiments, November 6, 7, and 8, 1907.

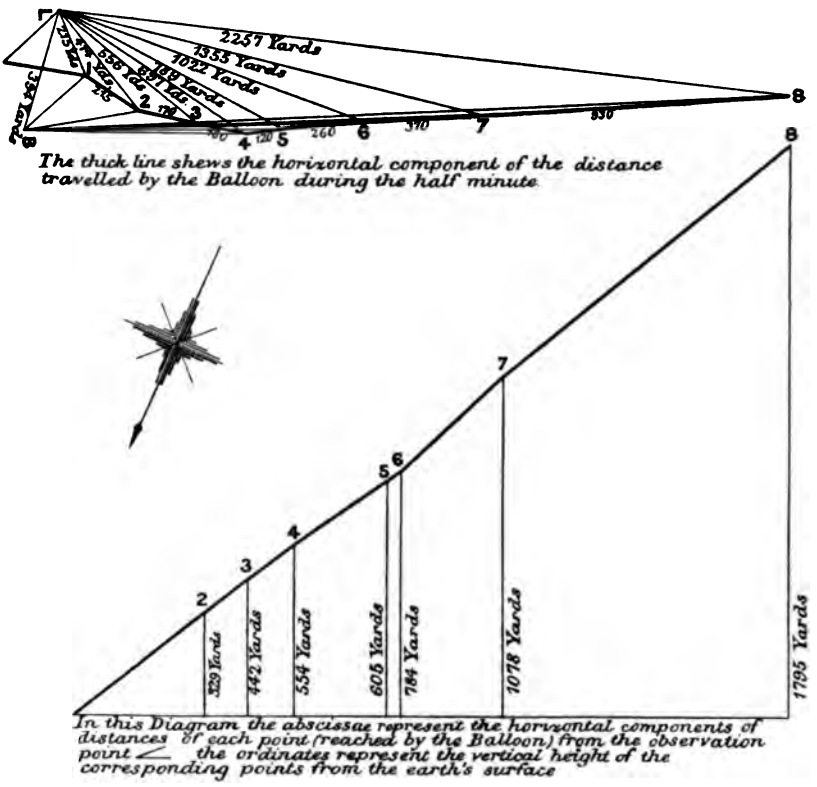
Date.	Readings:—Station A. Codrington.					Readings:—Station B.	
	Time.	Last visible.	Horizontal.	Vertical.	Remarks.	Horizontal.	Vertical.
			° ′	° ′			
Nov. 6	Morning	...	...	...	Not seen	Not seen	Not seen
,, 6	No. 1, 3.9 p.m.	...	...	...	Not seen	Not seen	Not seen
,, 7	No. 2, 8.23 a.m.	...	275	2 30	...	Not seen	
	8.23½ ,,	...	256	18			
	8.24 ,,	...	212	31			
	8.24½ ,,	...	159	33			
	8.25 ,,	...	...				
	8.25½ ,,	...	116				
	8.26 ,,	8.27 a.m.	114	24			
,, 7	No. 3, 2.18 p.m.	...	278 30	...	...	Not seen	Not seen
	2.18½ ,,	...	289				
	2.19 ,,	...	...				
	2.19½ ,,	...	...				
	2.20 ,,	...	276				
	2.20½ ,,	...	277 30				
	2.21 ,,	...	279				
	2.21½ ,,	...	280				
	2.22 ,,	...	280 30				
	2.22½ ,,	...	281				
	2.23 ,,	...	281 30				
	2.23½ ,,	...	281 45				
,, 8	No. 4, 9.24 a.m.	...	26	7 30	...	Not seen	Not seen
	9.25 ,,	...	1	23 30			
	9.26 ,,	...	334	40			
	9.27 ,,	...	327	45			
	9.28 ,,	...	299	50			
,, 8	No. 5, 2.24 p.m.	...	211	26	...	313° ′	33° ′
	2.24½ ,,	...	245	37	...	296	38 30
	2.25 ,,	...	251	35 30	...	284 30	38 30
	2.25½ ,,	...	254 30	31 30	...	279	38 30
	2.26 ,,	...	253	30	...	273	37 30
	2.26½ ,,	...	252	29 30	...	265	37 30
	2.27 ,,	...	251 30	29 30	...	259	38 30
	2.27½ ,,	2.29¼ p.m.	251	29	...	252	38 30

On the first day neither theodolite, and on the second day, morning and afternoon, and on the third day in the morning, only one of the theodolites succeeded in obtaining observations. Difficulties of light and clouds, and the small size of the balloons for the distances employed, prevented the other theodolite from either seeing or following continuously the flight. For the last ascent it was decided to greatly diminish the distance of the stations from each other, and to let off the

balloon at a point midway between and nearly on a line joining the observation stations.



On this occasion a complete double set of records was taken, and the results have been worked out by Messrs. Lingwood and Bowen, and their drawings are given in the accompanying figure.



They show that—

At a height of	The horizontal component of the wind's velocity was approximately
329 yards	430 yards per minute.
442 ,,	340 ,, ,,
554 ,,	320 ,, ,,
605 ,,	240 ,, ,,
784 ,,	520 ,, ,,
1078 ,,	740 ,, ,,
1795 ,,	1860 ,, ,,

TABLE II.—METEOROLOGICAL OBSERVATIONS TAKEN AT CODRINGTON HOUSE, ST. MICHAEL, BARBADOS, ON NOVEMBER 6, 7, AND 8, 1907, THE DAYS ON WHICH BALLOON EXPERIMENTS TO ASCERTAIN THE UPPER CURRENTS OF THE AIR WERE CARRIED ON. HEIGHT ABOVE SEA-LEVEL, 181 FEET.

Date and Time.	Barometric Pressure.	Attached Thermometer.	Thermometers.					Wind.		Clouds.		Total Amount.	Initial of Weather.	Remarks.
			Dry Bulb.	Wet Bulb.	Maximum.	Minimum.	Solar.	Direction.	Velocity.	Lower.	Upper.			
	ins.	°	°	°	°	°	°							
Nov. 6 at 8.0 a.m.	29·901	82·8	82·0	77·8	84·9	74·0	124·0	E.	7·0	Cum. Fr. cum.	Cirrus Cir. str.	5	C	Velocity—Mean of 24 hours, 8 a.m. 5th to 8 a.m. 6th.
8.30 ,,	...	...	...	...	...	...	...	E.	11·7	...	...	...	...	,, From 7.30 a.m. to 8.30 a.m. 6th.
9.0 ,,	29·915	83·6	83·6	77·2	84·9	74·0	124·6	E.S.	10·2	Cum. Fr. cum.	Cirrus	5	C	,, ,, 8 a.m. to 9 a.m. 6th.
2.0 p.m.	...	...	...	...	...	...	...	E.	7·2	...	...	...	...	,, Mean of 5 hours, 9 a.m. to 2 p.m.
3.0 ,,	29·831	86·0	84·0	77·4	86·7	82·4	138·0	E.S.	11·8	Cum. Fr. cum.	Cirrus	4	B	,, From 2 p.m. to 3 p.m.
Nov. 7 at 8.0 a.m.	29·877	82·6	82·2	77·2	84·7	73·4	119·0	E.N.	6·3	Cum. Fr. cum. Nimb.	Cirrus Cir. str.	6	C	,, Mean of 24 hours, 8 a.m. 6th to 8 a.m. 7th.
8.20 ,,	...	...	...	...	...	...	...	E.N.	14·4	...	...	...	...	,, From 7.30 a.m. to 8.20 a.m. 7th.
9.0 ,,	29·894	83·8	82·6	77·2	84·7	73·4	129·0	E.N.	16·5	Fr. cum. Cum. nimb.	Cir. str. Cir. cu.	8	C	,, ,, 8 a.m. to 9 a.m. 7th.
2.0 p.m.	...	...	...	...	...	...	...	E.N.	11·4	...	...	...	...	,, Mean of 5 hours, 9 a.m. to 2 p.m.
3.0 ,,	29·815	85·2	83·6	76·8	86·1	81·6	136·0	E.N.	8·1	Cum. Fr. cum.	Cir. str.	3	B	,, From 2 p.m. to 3 p.m.
Nov. 8 at 8.0 a.m.	29·895	81·6	81·2	75·6	84·5	68·6	121·0	E.	5·8	Cum. Fr. cum.	...	4	B	,, Mean of 24 hours, 8 a.m. 7th to 8 a.m. 8th.
8.30 ,,	...	...	...	...	...	...	...	E.	8·0	...	...	...	...	,, From 7.30 a.m. to 8.30 a.m. 8th.
9.0 ,,	29·912	83·0	82·0	75·8	84·5	68·6	122·0	E.	8·2	Cum. Fr. cum.	Cirrus	5	C	,, ,, 8 a.m. to 9 a.m. 8th.
2.0 p.m.	...	...	...	...	...	...	...	E.	5·7	...	...	...	...	,, Mean of 5 hours, 9 a.m. to 2 p.m.
3.0 ,,	29·835	84·8	82·6	76·6	85·9	82·0	135 2	E.	8·5	Cum. Fr. cum. Cum. nimb.	Cirrus	4	B	,, From 2 p.m. to 3 p.m.

The direction of the wind was approximately East of North-east.

It is noted that the rate of ascent of the balloon was much greater at higher elevations than near the earth.

Mr. J. R. Bovell's record of the meteorological observations at Codrington on the dates of the experiments are given in Table II.

To each balloon a linen label was attached written in English, French, and Spanish, asking for the return of the label with particulars of when and where found; but none have so far been received.

DISCUSSION.

Mr. C. J. P. CAVE said that he believed the reason the balloons were lost on these occasions was because they were sent up to windward and came over the heads of the observers. He understood that more hydrogen was to be sent out, and hoped that further observations would be made. It was an interesting locality, and he was glad that the Society was able to arrange for further observations.

Lightning and Compasses.

On 15th June last, in the vicinity of Rottnest Island, the P. and O. steamship *Britannia* (Capt. S. Barcham) was under the influence of a Westerly gale. The squalls were fierce, and the flashes of lightning seemed to be very close, although there was not any thunder heard. In the special meteorological log-book kept by Captain Barcham for the Meteorological Office, and also in a letter, he calls attention to the peculiar nature of the lightning experienced. The flash resembled that of a rocket bursting, and was at first supposed to be due to a rocket night-signal from the lighthouse. Immediately after the first flash the steering and the standard compasses (Lord Kelvin type) commenced to oscillate 45 degrees each way. The compasses were similarly affected on the occasion of each flash, but the needles came to rest between the successive flashes. There appeared a short note on the back of the *Meteorological Chart of the North Atlantic and Mediterranean* for June, which gave several instances of ships struck by lightning, on one of which occasions the compasses of the P. and O. steamship *Victoria* were affected. [This note is supplementary to that of the June issue on ships struck by lightning.[1]]—*Monthly Meteorological Charts of the North Atlantic and Mediterranean*, September 1908.

Australian Commonwealth Bureau of Meteorology, Melbourne.

This Bureau, which has recently been inaugurated by the Commonwealth Government at Melbourne, and is under the direction of Mr. H. A. Hunt, late of the Sydney Observatory, has got to work. Mr. Hunt not only issues the Daily Weather Chart of Australasia, which was commenced on January 1, 1908, and is the first example of one office issuing a daily map which gives the weather conditions for a whole continent, but he has also commenced the publication of a series of *Bulletins*, of which the first two are to hand. No. 1 deals with "The Climate and Meteorology of Australia," and No. 2, "The Rainfall Map of the Commonwealth of Australia."

Rainfall Map of Australia.

The Commonwealth Bureau of Meteorology has published a Rainfall Map of Australia, which has been compiled from observations taken during the

[1] See *Quarterly Journal*, p. 188.

decade ending 1906. This period has been adopted to enable an equitable comparison to be made with the records taken in the inland district of Western Australia, and in other parts of the interior where the figures are only available for a period not longer than ten years.

The records from nearly 700 stations have been used in the compilation of the map. The period dealt with has been an unusually dry one, especially over the northern and eastern parts, so that the averages given on the map in the earlier settled parts of the continent are much below what may be considered an approximation to the true means. In the letterpress which accompanies the map a table is given, showing the average for all the years available, together with the ten years' average for 168 stations which have averages varying from 67 years downwards. A casual glance at the map shows that the heaviest rainfall is over the northern and eastern parts of the continent; but while this is so, the most reliable, although lighter rains, are experienced over the south-western and south-eastern portions, including Tasmania. The driest part of Australia—that which receives a rainfall of 10 ins. and under—comprises an area which equals nearly one-third of the Commonwealth, and includes the central territory of South Australia, the extreme western parts of New South Wales, the south-western parts of Queensland, and the south-west, central, and part of the north-west portion of Western Australia. One million and eighty thousand square miles of the country, or over one-third of the continent, receives an average of from 10 to 20 ins.; and the remaining third enjoys abundant rain, ranging from 20 to 130 ins. per annum. The wettest part of the Commonwealth is situated about the Johnston River, on the north-east coast of Queensland, and on the west coast of Tasmania. The highest annual average recorded is 130 ins. at Geraldton, in the first-named state, and 114 ins. at Queenstown, in the second-named state. Sixty inches and over are annually recorded from several portions of the Queensland and New South Wales coasts, and also on the Southern Alps, on the border of New South Wales and Victoria. The smallest average annual rainfall in the Commonwealth is 3·8 ins., which occurred over a comparatively small area of country in the centre of the continent to the north of Lake Eyre.

International Geographical Congress at Geneva.

The Ninth International Geographical Congress was held at Geneva from July 27 to August 9. One of the Sections was devoted to Meteorology, Climatology, and Terrestrial Magnetism, the President of this section being Prof. Hellmann, of Berlin, and the Secretary, Dr. Alfred de Quervain, Zürich. Various Reports were presented to the Section, and M. Maurer, the Director of the Central Meteorological Institute of Zürich, exhibited a new Rainfall Map of Switzerland, which completed that of the late M. Bilwiller published in 1893. A report was also presented on the work published by the Geographical Society of Portugal, entitled "Elements of Nautical Meteorology." Prof. Hellmann described a new method of determining the average rainfall of a district, and Dr. Polis of Aix-la-Chapelle spoke of weather-forecasting and the use of wireless telegrams. Prof. Kassner described the uses of his Meteorological Globes, and Prof. Gautier read a paper on the climatology of the Grand St. Bernard.

OBSERVATIONS ON THE COLOUR OF LIGHTNING MADE AT EPSOM, 1903 TO 1907.

By SPENCER C. RUSSELL, F.R.Met.Soc.

[Read May 20, 1908.]

In the year 1903 I commenced a series of observations on the colour of lightning, and as these observations have now extended over a period of five years, I propose to lay the results before the Society. The great majority of the records have been made from Epsom Downs (450 feet above sea-level), where a practically clear horizon is obtainable in every direction, and the site is a very favourable one for viewing the reflection of lightning occasioned by storms in the Channel or neighbourhood of the coast. There is also a complete absence of artificial light, which is a *sine qua non* for carrying out observations on which a question of colour depends. My method of observation has been to keep a record of the colour or series of colours noted during each thunderstorm or display of sheet lightning, as the case may be, and to tabulate them under their respective colour, month, and year. The tables do not show the relative frequency of any particular colour or colours, only that particular colours or a single colour were noted during a storm or display of sheet lightning. My original intention was to endeavour to keep a record of the relative frequency of a particular colour, but very short experience showed me that it would be impossible to deal with every observation on such a footing. The term "fork lightning" must be understood as referring to observations of the direct flashes occurring during a thunderstorm, whilst that of "sheet lightning" includes either observations of light flashes taking place in the neighbourhood of the horizon, the reflection of lightning at a considerable distance, or the illumination of a cloud or clouds by a glow discharge, the direct flash being invisible.

After some consideration it was decided to tabulate the records into eight divisions of colour, those selected being red, blue, violet, orange, golden, yellow, white, and green. Even under this limited nomenclature considerable difficulty was experienced at times, more especially when dealing with those storms occurring during the daylight hours, in distinguishing between blue and violet, and golden and yellow, the general tendency of these pairs of colours being to grade into one another almost imperceptibly. Dealing with the results obtained of fork lightning, during fifty-seven storms (Table I.), these resolve themselves into fifteen sets of observations.

Red alone occurred nine times during the period, followed by red and blue eight, and blue alone seven. Red and blue in combination with other colours occurred fourteen times, whilst red combined with colours other than blue was seen six, and blue in combination with colours other than red once. White and yellow were also observed alone on two occasions respectively, all the others occurring in combination. The greatest number of colours seen during a single storm amounted to seven, these being red, blue, violet, orange, yellow, white, and green, taking place on three occasions.

Cyclonic thunderstorms of the winter months are accompanied by lightning either red or blue in colour, or in combination.

TABLE I.—Combination of Colours (Fork and Sheet Lightning) and Number of Times observed during 1903-07.

Fork Lightning.

Red.	Blue.	Violet.	Orange.	Golden.	Yellow.	White.	Green.	1903.	1904.	1905.	1906.	1907.	Total.
R	...	...	...	...	...	...	...	4	2	1	1	1	9
R	B	...	...	...	...	...	...	1	1	1	2	3	8
...	B	...	...	...	...	...	...	1	2	1	2	1	7
...	...	...	...	G	...	W	...	2	2	1	...	1	6
R	...	...	...	G	Y	...	...	4	...	1	...	1	6
R	B	V	O	...	Y	W	Gr	...	...	...	2	1	3
R	B	V	O	G	...	W	...	...	...	1	1	1	3
R	B	V	...	G	...	W	...	2	...	...	...	1	3
R	B	V	...	G	Y	W	...	...	1	...	...	1	2
R	B	...	...	...	...	W	...	2	...	..	...	...	2
...	...	V	...	...	...	W	...	...	1	1	...	...	2
...	...	...	...	...	...	W	...	...	1	1	...	...	2
...	...	...	...	...	Y	...	...	...	...	1	...	1	2
...	B	V	...	G	Y	W	Gr	...	...	...	...	1	1
R	B	...	O	...	...	W	...	...	...	...	1	...	1
			Total					16	10	9	9	13	57

Sheet Lightning.

Red.	Blue.	Violet.	Orange.	Golden.	Yellow.	White.	Green.	1903.	1904.	1905.	1906.	1907.	Total.
R	...	...	...	...	...	...	...	...	2	2	3	2	9
...	...	...	...	...	Y	...	...	1	1	...	2	5	9
...	...	...	...	...	...	W	...	2	1	1	1	4	9
R	...	...	...	G	...	...	...	1	...	1	...	5	7
...	...	V	...	...	...	...	...	1	...	2	1	3	7
...	...	...	...	...	Y	W	...	3	1	1	1	...	6
...	...	...	...	G	...	...	...	...	1	...	1	4	6
...	B	...	...	...	...	W	...	1	2	...	1	1	5
...	B	...	...	...	...	...	...	...	1	1	1	2	5
...	...	...	O	...	...	...	...	1	...	...	1	3	5
...	...	...	...	...	...	W	Gr	1	...	...	...	2	3
...	B	V	...	...	...	W	...	...	...	...	2	...	2
...	...	...	...	G	Y	...	Gr	...	...	...	1	1	2
R	B	...	...	...	..	...	Gr	...	...	...	...	1	1
...	B	V	...	...	...	...	Gr	...	...	...	...	1	1
...	...	V	O	...	...	W	...	...	...	...	...	1	1
			Total					11	9	8	15	35	78

The observations of sheet lightning, amounting to seventy-eight (Table I.), divide themselves into sixteen sets of observations, red, yellow, and white alone being seen nine times each, violet seven, golden six, and blue and orange five. In sheet lightning green was the only colour that was not observed alone; the remainder of the observations, as

will appear from the table, were made up of colours in combination. The maximum combination of sheet lightning colours has not exceeded three.

The greatest contrast arising from a comparison of the two portions of the table is the frequency of sheet lightning to be of a single colour: out of the eight colours seven occurred separately, whereas in fork lightning only four colours were noticed as occurring singly. The marked predominance of red and blue, as disclosed by the observations of fork lightning, is not borne out in anything like the same degree in sheet lightning, the tendency of the latter being for a more equal distribution of colour.

In the severe thunderstorm of May 31, 1903, the commencement, and, in fact, the greater part of the storm was marked by a predominance of red, blue, and violet colours, which, as the storm progressed towards its end, tended to fade away into golden and white.

The thunderstorm of April 13, 1904, occurred during the hours of darkness, and was therefore favourable for observations; the colours during the latter part of the storm again faded away to golden, yellow, and white.

A very severe thunderstorm occurred in the neighbourhood of the Thames Valley on May 8, 1906. As seen from Epsom it was situated to the westward. The storm was of considerable duration with a brilliant display of lightning, no less than seven colours being noted. It may be described as a white and yellow storm, these two colours being the markedly prevalent ones, the distribution of red, blue, and violet occurring during the middle period of the storm.

The Guildford storm of August 2, 1906, was a distinctly blue and red one during the greater part of its continuance. The storm occurred at a considerable height, and to that fact, and to the prevalence of moonlight during the greater portion of the storm exercising an influence on the lighter colours, I attribute the excessive frequency of blue and red. During the latter part of the storm there was again a fading away to golden and white. It is somewhat difficult to generalise on the results obtained from these four storms, but the tendency is for the beginning and middle period to be associated with the more brilliant colours, while towards the end there is a fading away, and change both of colour and intensity. This may be in a great measure attributable to the increasing distance of the lightning.

A summary of the relative frequency of colour during the four storms as given in Table II. discloses the fact that the colours follow exactly the same order as those of fork lightning as deduced from the yearly tables. I believe that this is only a coincidence which would probably disappear if more individual storms had been treated with regard to relative frequency of colour.

TABLE II.—Colour of Fork Lightning in Order of Relative Frequency as Deduced from Observations of the Thunderstorms on May 31, 1903; April 13, 1904; May 8, 1906; and August 2, 1906.

Red.	Blue.	White.	Golden.	Violet.	Yellow.	Orange.	Green.
110	100	91	71	63	57	26	12

Cause of the Colour of Lightning.—The various colours which lightning affects appear to depend upon the following circumstances:—(1) The height of the storm; (2) The electrical energy; (3) The density of the air; (4) The moisture of the air; (5) Substances suspended in the air; and (6) The distance of the flash from the place of observation.

The green flashes, although of very infrequent occurrence, apparently take place at the greatest height, being followed by blue and violet, as these three colours are frequently noticed playing over and above the others.

It would seem that the presence of hail, when occurring in association with a thunderstorm, is intimately connected with blue lightning. I have tabulated the storms during which hail occurred during the five years, together with the colour of the lightning seen (Table III.), from which it will be noticed that on five occasions red and blue in combination occurred alone, blue on three alone, and varying colours on two, of which on one red and blue, and on the other blue, entered into the composition.

TABLE III.—Thunderstorms accompanied by Hail, 1903 to 1907.

Date.	Red.	Blue.	Violet.	Orange.	Golden.	Yellow.	White.	Green.
May 30, 1903 .	R	B	...	...	...	...	...	...
March 29, 1904 .	R	B	...	...	...	...	...	...
,, 30, 1904 .	...	B	...	...	...	...	...	...
,, 15, 1905 .	...	B	...	...	...	...	...	...
January 9, 1906 .	R	B	...	...	...	...	...	...
February 8, 1906	R	B	...	...	...	...	...	...
April 22, 1906 .	...	B	...	...	...	...	...	...
August 2, 1906 .	R	B	V	O	G	...	W	...
,, 6, 1907 .	...	B	V	...	G	Y	W	Gr
,, 11, 1907 .	R	B	...	...	...	...	...	...

Rain has considerable influence on the colours: before its commencement the brightness of the colours is much intensified; falling rain causes considerable diminution of colour, and even after cessation the colours do not brighten up in any marked degree. A partially cloudy sky is very much better for gathering the variability of colour than a completely overcast one. Artificial illumination exercises in a marked degree an effect on colour. Observations made under these circumstances show that red and orange are to all intents and purposes incapable of separation, the latter colour grading into the former, whilst the distinction of golden and yellow is impossible; at the same time it does not appear to exercise any effect on the distinction of blue and violet, this latter being in exact opposition to that experienced during the daylight hours.

During warm weather showers at night are often accompanied by a form of sheet lightning occurring above the shower cloud. I have frequently traced these showers with lightning from south-west to north-east; the light displayed is very feeble, amounting at times to little more than a glimmer, the colour varying from silvery grey to straw. To avoid duplication these colours have been entered as white and yellow respectively. I mention this observation as showing in some small degree the difficulty that arises at times as to under what description a colour shall

be entered. The observations I have obtained on the variation of colour, with the distance of the flash from the place of observation, point to the fact that distant storms are accompanied by lightning the prevailing colour of which is of a light hue.

On many occasions an apparent connection was noted to exist between the colour of the lightning and the subsequent thunder. Red is followed by thunder of a long rolling nature; blue by thunder in peals, varying both in intensity and duration of sound; white by thunder as nearly as possible resembling the rapid discharge of ordnance; whilst violet and green are followed by the most intense discharge of all.

TABLE IV.—Colour of Fork Lightning in Order of Occurrence.

Red.	Blue.	White.	Golden.	Violet.	Yellow.	Orange.	Green.
37	30	25	21	14	14	7	4

The observations of fork lightning (Table IV.) show red to be of the most frequent occurrence, followed closely by blue; the colours thence descend in fairly regular order to orange and green. White is of the greatest frequence in sheet lightning (Table V.), red and yellow being equal. Blue descends to a somewhat low place on the list, being fifth as compared with fork lightning; orange and green change places.

TABLE V.—Colour of Sheet Lightning in Order of Occurrence.

White.	Red.	Yellow.	Golden.	Blue.	Violet.	Green.	Orange.
26	17	17	15	14	11	7	6

A combination of the two sets of observations still leaves red at the head of the list (Table VI.), followed very closely by white, and blue third in order. Golden appears fourth in all three tables.

TABLE VI.—Colour of Fork and Sheet Lightning Combined in Order of Occurrence.

Red.	White.	Blue.	Golden.	Yellow.	Violet.	Orange.	Green.
54	51	44	36	31	25	13	11

DISCUSSION.

Mr. J. A. Curtis asked if any particular method was adopted for determining the colour of the lightning. He wished to congratulate Mr. Russell upon his energy and perseverance in taking the observations.

Mr. W. W. Bryant enquired what effect, if any, Mr. Russell had noticed due to the frequency of the discharge. One would expect for physiological reasons that with two flashes occurring at a very short interval, the second would be of the complementary colour to that of the other. Storms with frequent flashes would in this way tend to come under Mr. Russell's red and blue class of lightning.

Mr. W. MARRIOTT said that the subject of lightning was a very fascinating one. In 1888 the late Mr. Symons read a paper on the "Results of an Investigation of the Phenomena of English Thunderstorms," which he had carried out during the years 1857-59. It was one of his earliest papers, and he had begun by collecting observations of thunderstorms and discussing the frequency, the damage done, and the colour of the lightning. The following extract gave a very interesting summary of the results with regard to the colour of lightning:—

"I may perhaps, before stating the results obtained, explain that I have been obliged either to reject or reduce to some of the primary colours the terms employed by some of the observers, such as 'like sulphur flame,' 'like a burning rope,' 'mauve,' etc. On separating the records into the two classes of sheet and forked lightning, I find that, in sheet lightning the most prevalent colour is white, then yellow, blue, and red; in forked lightning, however, the order is nearly reversed, blue being more than twice as frequent as any other colour, then red, white, and most rarely yellow. Blue (or violet) is by far the most frequently recorded colour. In every case but two where I have received communications from persons who have been themselves, or whose houses have been, struck by lightning, and the colour has been mentioned, it has been stated to be blue or violet. The exceptions were red at Ryther School, and yellowish-white with a tinge of blue at Wibsey, near Bradford. Sheet lightning is seen about twice as often as forked."

Mr. Marriott said that the Society took up the investigation of thunderstorms in the years 1888-1889, and one of the questions on the form for the observers to fill up was that of the colour of the lightnings. He had not time to go into all the phases of thunderstorms, and had not been able to take up the question. However, should any one wish to continue the subject, there was much interesting information available, which might be of assistance.

Colonel H. E. RAWSON said that considering the subject from a purely scientific point of view, perhaps Mr. Russell would like to know of a very curious incident during a thunderstorm in South Africa. There was such a charged electrical atmosphere, that though the storm was only visible on the horizon, the covering of the electric wires in his house had become a conductor, that is to say, the insulation round the wires became a conductor, and the current from the town circuit sparked across from one wire to the other, causing the fall of a pendant. The insulation was the ordinary silk covering. Probably such a condition of the atmosphere affects the colour of a flash, just as moisture in the lower levels affects the colours at sunset. The above incident was not an uncommon one during a distant thunderstorm, and he had investigated another case which could only be explained in the same way.

THE PRESIDENT, Dr. H. R. MILL, said the paper was interesting in showing the results of observations made without the use of instruments. His own attitude was more inclined towards questioning rather than commenting. There was one suggestion, however, he would like to make, and that was that if possible observations of lightning flashes should be made with a spectroscope to show whether the changes in colour were due to the physiological effect referred to by Mr. Bryant, or if they had a real basis. Where a disruptive discharge took place, the substances in the air must necessarily determine the colour of the flash.

Mr. S. C. RUSSELL, in reply, said that as regards Mr. Curtis's enquiry as to colour, this had been settled by his own judgment. Colonel Rawson's description of the phenomena he had witnessed, he (Mr. Russell) would call an instance of electrical energy.

AN ELEMENTARY EXPLANATION OF CORRELATION: ILLUSTRATED BY RAINFALL AND DEPTH OF WATER IN A WELL.

By R. H. HOOKER, M.A., F.R.Met.Soc., F.S.S.

[Read June 17, 1908.]

I AM desirous in the present paper of calling attention to recent methods of dealing with statistics, and more particularly with the process of correlation, and to illustrate, by working out a special example, what results can be obtained. This paper is therefore to be regarded rather as an explanation of the method than as a rigorous procedure to be followed in every case. The procedure appropriate to each particular problem requires to be carefully considered, and we must in each case try to form a clear idea of exactly *what* we are comparing or correlating, and whether, in fact, correlation will give the answer sought. To do this requires a more intimate acquaintance with the science of statistics than can be condensed into the following few pages. But I want to enable all who read these remarks to appreciate the value of the method, so that they may give credence to facts ascertained by experts, even although they may not themselves follow the whole of their work; and also, perhaps, persuade some to study the subject.[1] This is my own position: I am not enough of a mathematician to do more than work out a few problems; and it occurred to me therefore that, being on the same plane as so many others, I might possibly make myself understood better than would a scientist. I have so often myself, when introduced to a new subject, asked: "What is the good of it?" that I have felt emboldened to attempt to make others understand what is the good of correlation.

For the purpose of the present paper, I propose to regard the *correlation coefficient* as a "measure of the resemblance of two sets of observations," and as a corollary, as a measure of the dependence of one phenomenon upon another.

Consider, for instance, the diagram (Fig. 1) which is of a very common form. In this the measurements made of the rainfall (expressed as differences from the average) during a particular period in successive years are plotted at certain regular intervals, and all the points joined by straight lines; the measurements made of the depth of water in a well, with which we wish to compare the rainfall, are also similarly plotted in such a way that the measurements of the same year fall on the same vertical line.

It is clear that in this example there is considerable resemblance between the two "curves" thus drawn: *i.e.* in many cases a rise in the full line is accompanied by a rise in the dotted line, and a fall in the one is generally accompanied by a fall in the other. If this only occasionally happened, we should say that the coincidence of a rise in both curves was accidental, but in this case the correspondences are so numerous that we say there is evidently a connection between the two curves.

[1] Those who wish to study correlation will find suitable introductions in *Elements of Statistics*, by A. L. Bowley; or "On the Theory of Correlation," by G. U. Yule (*Journal of the Royal Statistical Society*, Dec. 1897).

The mere enumeration of several coincidences, or their mere exhibition on a diagram, however, is not by any means a satisfactory proof of connection; and what is wanted is a reliable test of whether the coincidences are due to the one phenomenon acting upon the other, or whether they are simply accidental. Such a test is provided by the method of correlation, which will, moreover, give a useful measure of the degree of connection between any two such curves.

Before we can ascertain if the variations of one phenomenon are due to those of another, we must first know what is the ordinary measurement we should expect to find if the second phenomenon were not variable; and we must also know how far the measurements are apt

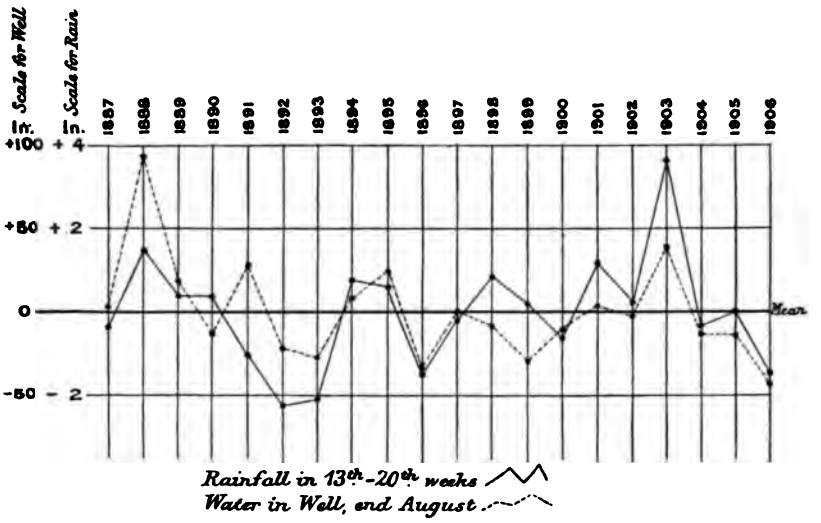


FIG. 1.

to vary naturally from chance causes. The leaves on a particular tree, for instance, are not all of the same size. If we are given several large leaves, we cannot say off-hand that they are due to, say, a heavy rainfall having produced very large leaves on the trees; we must know first what is the size of an ordinary leaf on most trees of the same species, and secondly whether the leaves on an ordinary tree are so variable that the particular size, although large, is still fairly common. When we are satisfied that the leaves are bigger than usual, and also so large as to be out of the common, we suspect a particular cause; but before we are satisfied that a heavy rainfall is that particular cause, we must know whether the rainfall *was* heavy. We must find out also whether it was exceptional, or whether similar rainfalls have occurred before without producing large leaves; in the latter case we should say at once that it was a mere coincidence, and search for some other cause.

Therefore, before we can compare corresponding observations of two particular objects or phenomena, we must have some measure of their ordinary size; and also some measure of their natural variability, *i.e.* of

their *deviations* from that ordinary size. In the first place, consequently, I must explain two terms, viz. (1) *average*, and (2) *standard deviation*.

The best way of giving people some notion of the size of a number of objects, or measurements, is of course to show them the whole collection. But this is frequently impracticable or inconvenient, and we therefore mention one particular size which will give the best idea we can of the whole collection. Such a representative number may be termed an *average*. The average most commonly used is that obtained by adding together all the measurements, and dividing the total by the number of measurements. We might say, for instance, that the average size of a cherry is half an inch in diameter. By this we do not mean that every cherry is half an inch in diameter; but that, if a large number are taken, half an inch gives a fair idea of most of them, and we can, for example, form a very good notion of the space necessary to store a given quantity. Similarly, if we say that the average rainfall in April at a certain place is 2·5 ins., we do not mean that the rainfall every April will be 2·5 ins., but that during the past fifty years the total rain that has fallen in April was 125 inches.

We must now lay down a formula for the average. Let X_1 stand for one particular measurement of the phenomenon or object, and X_2 X_3, . . . X_n stand for the other measurements, there being n measurements in all. Then, for convenience we may say that X is a variable amount representing any one of the measurements. If, for instance, we are considering April rainfall, X is a symbol which stands for "April rainfall of any year." The formula for the average may be written $\bar{x} = \frac{X_1+X_2+X_3+ \ldots +X_n}{n}$, or more shortly $\bar{x} = \frac{\Sigma X}{n}$, where the Greek capital letter Σ stands for "sum of all the quantities denoted by" X. The quantity $\bar{x}$ is more strictly called the *arithmetic average*, or *arithmetic mean*, frequently abbreviated to "average" or "mean" simply. There are certain other useful representative "averages," among which the following may be mentioned: (1) the median. This is possibly the simplest of all; it is obtained by ranging all the measurements in order, the smallest at one end, and the greatest at the other, and picking out the middle value. If there are $2_n - 1$ measurements, X_1, X_2 . . . X_{2n-1}, the median is X_n; or if there be an even number of observations (2_n) it is $\frac{X_n+X_{n+1}}{2}$. Its chief interest is that there are just as many measurements above as below it, and it may be conveniently quoted in cases where it is desired to know the quantity above or below which values are equally likely to occur.

(2) The *mode* is perhaps the most truly representative average of all, and is the measurement which is likely to occur most frequently: its calculation is, however, difficult. If all the n measurements be arranged in order, it will be found that many values occur frequently; a particular value p, for instance, will occur q times. An arrangement showing how often each value occurs is termed a *frequency distribution*, and a certain value will be found for which q is a maximum; this value will usually be quite near the mode. If the number of observations, instead of being a limited number n, be supposed increased indefinitely, we obtain a *theoretical* frequency distribution, and the most frequent value of this theoretical distribution is called the *mode*. It is in fact the theoretically most frequent value, and not merely the value actually occurring most often

in the more or less limited number of observations at our disposal. The word is derived from the French "mode" = fashion, and represents the most fashionable value. Various elementary methods of finding an approximation to the mode are given in textbooks.

The different advantages of the three above-mentioned forms of average may be illustrated as follows: If you wish to forecast the total rainfall of the next fifty years, take the arithmetic mean as your standard; if you wish to bet that the rainfall next year will be more or less than a certain amount, take the *median*; if you wish to foretell next year's rainfall, your best chance is to take the *mode*.

It may be noted that if the various measurements are quite evenly distributed in the same way on either side of the arithmetic mean, then mean and median coincide; and except in a few rare cases where extreme values are commoner than intermediate values (*e.g.* proportion of sky clouded), the mode also coincides with them.

Another form of average, commonly used in certain cases, is the *geometric mean*, $g = \sqrt[n]{X_1X_2X_3 \ldots X_n}$ or $\log g = \frac{1}{n}\Sigma (\log X)$. This is generally used to calculate increases of population, or for finding "averages" of such phenomena as tend to increase or decrease in a constant ratio.

In what follows, the only average I shall use will be the arithmetic mean, which I shall abbreviate to "mean" simply.

The mean is thus the first thing we require to know concerning the measurements of a group of variable objects. But this gives only a very crude idea of them, and the next most useful piece of information is: How much do individual objects differ from the mean; are some of them very small and others very large, or are they all nearly the same size? We want, in fact, a measure of the way in which they are *scattered* about the mean. Consider the rainfall of April, for instance, at a town where the mean is $2\frac{1}{2}$ inches; we may occasionally—very rarely—find it 0 inches, or again we may quite easily get 5 inches or more, the range being thus at least twice the mean. On the other hand, examine all the ripe cherries from a single tree served in a dish at dessert; their mean diameter is perhaps half an inch, but you will not find any of them over an inch in diameter, nor any of 0 inches; in fact they will all be not far from the half inch; still they are not all of the same size. We should say that the rainfall has a much greater range than the cherries in a dish, and is much more variable.

A measure of this variability is clearly wanted in many cases. A municipality which is laying down a system of drainage does not care twopence about the mean rainfall per day or per hour; this would only be of use if a drainage system could be devised which would store any fall above the mean, and run it off when the rain had ceased falling. On the other hand, it need not provide for an absolute maximum that is liable to occur, say, once in 2000 years. Rather than go to the great expense of preparing for that, it would be cheaper to suffer the damage. A fall of 1 in. in an hour is not unknown in this country, hence 24 ins. in a day is not on the face of it impossible, but a municipality need not provide for the latter. What is wanted is a measure that will give an idea of how often excessive falls are likely to occur.

A simple measure of the variability of a group of measurements is

obtained by finding the difference between each measurement and the mean, *i.e.* its *deviation* from the average (irrespective of sign), adding all these differences together, and dividing by the number of measurements. This gives the "mean deviation." But a better measure is what is known as the *standard deviation*. This is obtained by adding together the *squares* of the deviations, dividing the total by the number, and extracting the square root of the quotient.

If we call the deviations[1] from the mean x_1, x_2, x_3 . . ., so that $x_1 = X_1 - \bar{x}$, or generally $x = X - \bar{x}$, then the standard deviation, usually denoted by the Greek letter σ, $= \sqrt{\frac{\Sigma x^2}{n}}$.

For most purposes this quantity is the best measure of the variability. Among its practical advantages may be noted the following: — (1) Like the ordinary arithmetic mean, it is constantly of use in further calculations; (2) It will be found that practically half the number of observations differ from the mean by less than two-thirds of the standard deviation.[2] In other words, it is about an even chance that the rainfall next month will not differ from the mean by an amount exceeding two-thirds of the standard deviation. (3) A value differing from the mean by three times the standard deviation only rarely occurs.[2]

It may be noted that the sum of the squares of the deviations from the mean is the least possible; and hence in this sense it may be said that the observations as a group are closer to the mean than to any other value. [The mean deviation is least when the deviations are measured from the *median* and not from the mean.] For, suppose the deviations (y) to be measured from some value other than the mean, and let d be the difference between this other value and the mean ($\bar{x}$), then, for any value X,

$$y = x - d\,;\ y^2 = x^2 - 2xd + d^2.$$

$$\Sigma(y^2) = \Sigma(x^2) - 2\Sigma xd + \Sigma d^2 = \Sigma(x^2) + nd^2$$

(since the sum of the deviations from the mean, by definition, $= 0$, hence $\Sigma xd = 0$), and therefore Σy^2 is least when $nd^2 = 0$, *i.e.*, $d = 0$.

Take, for instance, the full black curve in Fig. 1: this represents the rainfall at Cirencester during the thirteenth to twentieth weeks of each year from 1887 to 1906 (end of March to beginning of May). The horizontal black line—denoted by O—represents the mean rainfall of that period in those twenty years, viz. 3·29 ins. The standard deviation is 1·32 in. I find upon examination of the records that in those twenty periods the rainfall differed from the mean by 0·88 in. or more in eight years only out of the twenty; while the greatest deviation was 3·66 ins., or about $2\frac{2}{3}$ times the standard deviation. Again, the standard deviation of the dotted curve in the diagram (depth of water in the well at a certain date) is 30 ins.; in just ten cases the deviation was less than 20 ins.

[1] As we are going to square these differences, it does not matter whether X is greater or less than $\bar{x}$.

[2] (2) and (3) only hold strictly when the distribution of the measurements about the mean is "normal," or approximately so. If the frequency distribution be plotted on a curve of which the abscissae represent the values, and the ordinates the number of times each value occurs, a "frequency curve" is obtained. If this is of the "cocked-hat" shape, showing a maximum at the centre and tailing off symmetrically at either end, with an equation of the form $y = ae^{-\frac{x^2}{2\sigma^2}}$, the frequency distribution is called *normal*.

Now we can get on to correlation.

Let us consider again the diagram. We saw that in most cases a big deviation above the mean in one curve is accompanied by a considerable deviation above the mean in the other; while deviations below the mean also commonly come in the same years. Now we all probably know that if we multiply a positive quantity by another positive quantity, the product is positive; and that if we multiply a negative quantity by a negative, the product is also positive; the product being negative only when a positive is multiplied by a negative quantity. Let us call all deviations above the mean, in either of these two curves, positive, and all deviations below the mean, negative. Then if for each of the years we multiply the deviation of one curve from its mean by the deviation of the other from its mean, we see that we have a great many cases where we multiply positive by positive or negative by negative; hence we get many positive products and few negative. Moreover, the biggest deviations of one curve generally correspond to big deviations, on the same side, of the other; hence our positive products are mostly large. If we then add all our products together, we shall have a large positive total. And therefore it is fairly obvious that the more two such curves are alike, the bigger is the positive total.

If we denote deviations from the mean in the full black curve by x, and deviations in the dotted curve by y, then the sum of the products thus obtained is $x_1y_1 + x_2y_2 + x_3y_3 + \ldots + x_ny_n$, there being n values of each of the two variables measured. Or, generally, this may be expressed as $\Sigma(xy)$, *i.e.*, the sum of all quantities like x multiplied by y. So that the more our curves are alike the bigger is $\Sigma(xy)$.

Thus this method gives us the germ of a measurement. But we must know something more: we have a big total, but we do not know *how* near it is to the biggest possible, and therefore how near the two curves are to absolute resemblance. As a matter of fact, the greatest value of this quantity is $n\sigma_x\sigma_y$, and accordingly the *correlation coefficient*, as it is called, is obtained by dividing $\Sigma(xy)$ by n times the product of the standard deviations (σ_x and σ_y) of the two curves, *i.e.*, the correlation coefficient $r = \frac{\Sigma(xy)}{n\sigma_x\sigma_y}$. Now, (1) r always lies between the limits ± 1. (2) If the two curves are so alike that they both rise and fall together, and always in the same proportion, $r = +1$ exactly. (3) If when one goes up the other always goes down, and also always in the same proportion, $r = -1$ exactly. [If we were to correlate any curve with its reflection in still water, r would $= -1$.]

For, $n^2\sigma_x^2\sigma_y^2 - (\Sigma xy)^2 = \Sigma x^2 \Sigma y^2 - (\Sigma xy)^2$, since $\sigma_x = \sqrt{\frac{\Sigma x^2}{n}}$ and $\sigma_y = \sqrt{\frac{\Sigma y^2}{n}}$.

Let $x_1 = \lambda_1 y_1$, $x_2 = \lambda_2 y_2 \ldots$, then $n^2\sigma_x^2\sigma_y^2 - (\Sigma xy)^2 =$

$$(\lambda_1^2 y_1^2 + \lambda_2 y_2^2 + \ldots)(y_1^2 + y_2^2 + \ldots) - (\lambda_1 y_1^2 + \lambda_2 y_2^2 + \ldots)^2$$
$$= y_1^2 y_2^2(\lambda_1^2 + \lambda_2^2 - 2\lambda_1\lambda_2) + \ldots$$
$$= y_1^2 y_2^2(\lambda_1 - \lambda_2)^2 + \ldots,$$

which is 0 if $\lambda_1 = \lambda_2 = \lambda_3 \ldots$, but is otherwise positive.

Hence Σxy cannot be greater than $\pm n\sigma_x\sigma_y$, and therefore r lies between ∓ 1. Also, therefore, when $\lambda_1 = \lambda_2 = \lambda_3$, *i.e.* when $x = \lambda y$, $r = +1$ exactly.

If there is no correspondence whatever between the two curves, *i.e.*

if a big positive deviation in the one is accompanied sometimes by a big positive deviation in the other, sometimes by a negative, and sometimes by no deviation; in fact, if it is pure chance what deviation you get in the second curve with a given deviation in the first, then $r = 0$. Hence the more one curve is dependent upon the other and resembles it, the greater is r, positive if an increase in the one causes an increase in the other (*e.g.* spring rainfall and yield of hay), and negative if an increase in the one causes a decrease in the other (*e.g.* autumn rainfall and subsequent yield of wheat per acre).

It is clear therefore that the correlation coefficient gives us an excellent measure of the resemblance of two sets of observations; and consequently of the dependence of the one upon the other.

Now let us apply the method to a concrete problem. The opinion is usually held that a deficiency of winter rainfall is the cause of scarcity of water in the following summer. *E.g.*, the late Mr. G. J. Symons, in *The Times* of March 31, 1891, said, "I do not diverge into the effect of this drought" [*i.e.* of the preceding winter] "upon the yield of springs and wells during the summer." In two papers read before this Society by my brother, Mr. C. P. Hooker, in 1903 and 1907,[1] this view was emphatically challenged, and he concluded, as the result of his investigations, that plenty or scarcity during summer depended, not on the winter rains, but on the spring rains, more particularly during March and April. We have thus two opposite contentions, the one authority attributing scarcity to a dry winter (October to February or March), the other to a dry spring (March and April). I propose to measure the relationship between the depth of water in a well in summer and (*a*) the winter rainfall, (*b*) the rainfall at various periods in the spring.

The data are all given in my brother's two papers. One point only need be considered here, viz. the date in summer to be chosen. "Scarcity" is probably best measured by the minimum amount of water in the well; but, owing to the different times at which the replenishing autumn rains set in, the date at which this minimum occurs varies enormously. A scarcity in early autumn may often be prevented by heavy rains setting in in September; on the other hand, there may be plenty of water in the well at the end of August, and two months' absence of rain may cause a serious deficiency by November. It is thus desirable to take our well-measurements at a sufficiently early date to eliminate the disturbing factor of the autumn rains. I have accordingly taken the last week in August as the best.[2]

In the first place I shall correlate the well-depth at the end of August with the rainfall of the 13th-20th weeks of the year (this is approximately the period indicated by my brother); and I propose to give the whole work in detail as an example (see Table I.)

A table with several columns must be formed. First write down on the left-hand side the successive years of the period. In the next column write the depth of water in the well at the date chosen (last week in August); add the items, divide by the number of years (20) and we have

[1] *Quarterly Journal of the Royal Meteorological Society*, 1903, **29**, p. 263, and 1907, **33**, p. 287.

[2] Except that in the wet summer of 1891, when a heavy rainfall in the fourth week of August (2·50 ins.) percolated to the well and raised its level by 8 ft., I have taken the measurement of the third week in August.

the mean depth at the end of August (72 inches). In column 3 write the deviation (x) of the well-depth each year from the mean; *i.e.* subtract each one successively from the mean, and mark it positive if the depth be greater than the mean, negative if it be less.[1] In column 4 write the square of each of the numbers in col. 3; the sum of these squares is n times the square of the standard deviation, $n\sigma_x^2 = 18{,}094$ (whence σ_x can be obtained at once if wanted). Similarly, in the next three columns write (5) the rainfall of the 13th-20th weeks, and calculate its mean, (6) the deviation (y) of each rainfall from its mean, and (7) the squares of these deviations; adding these last we have $n\sigma_y^2 = 34{\cdot}763$. Finally, in col. 8 write the product obtained by multiplying the corresponding deviations given in cols. 3 and 6, being very careful about the sign of the

TABLE I.

Year. 1	Well-depth.			Rainfall.			8 xy.
	2 X.	3 x.	4 x^2.	5 Y.	6 y.	7 y^2.	
	Ft. ins.	Ins.		Ins.	Ins.		
1887	6 3	+ 3	9	2·89	−0·40	0·160	− 1·2
1888	13 10	+94	8,836	5·83	+1·54	2·372	+144·7
1889	7 8	+20	400	3·68	+0·39	·152	+ 7·8
1890	4 11	−13	169	3·70	+0·41	·168	− 5·3
1891	8 3	+27	729	2·23	−1·06	1·124	− 28·6
1892	4 2	−22	484	1·07	−2·22	4·928	+ 48·8
1893	3 8	−28	784	1·20	−2·09	4·326	+ 58·5
1894	6 8	+ 8	64	4·07	+0·78	·608	+ 6·1
1895	8 1	+25	625	3·91	+0·62	·384	+ 15·5
1896	3 3	−33	1,089	1·75	−1·54	2·372	+ 50·8
1897	5 11	− 1	1	3·08	−0·21	·044	+ 0·2
1898	5 2	−10	100	4·15	+0·86	·740	− 8·6
1899	3 6	−30	900	3·41	+0·12	·014	− 3·6
1900	5 2	−10	100	2·64	−0·65	·422	+ 6·5
1901	6 3	+ 3	9	4·45	+1·16	1·346	+ 3·5
1902	5 9	− 3	9	3·49	+0·20	·040	− 0·6
1903	9 1	+37	1,369	6·95	+3·66	13·396	+135·4
1904	4 9	−15	225	3·04	−0·25	·063	+ 3·7
1905	4 8	−16	256	3·33	+0·04	·002	− 0·6
1906	2 4	−44	1,936	1·84	−1·45	2·102	+ 63·8
Total	119 4	...	18,094	65·71	...	34·763	+496·8
Average	6 0	...	...	3·29	...	...	...

product. Add up all the positive products (+ 545·3) and from this total subtract the sum of all the negative products (− 48·5): the remainder is + 496·8, which = $\Sigma(xy)$. Divide this by the square root of the product of the totals in cols. 4 and 7, *i.e.* $\sqrt{n\sigma_x^2 \times n\sigma_y^2} = n\sigma_x\sigma_y = 793{\cdot}1$, and the quotient is the correlation coefficient, $r = + 0{\cdot}63$.

This is a tolerably high coefficient, and indicates that there is a distinct connection between the rainfall of the period considered and the depth in the well at the end of August.

We must now consider the probability of this connection being real or accidental. This involves a good deal more mathematics, and depends

[1] In practice, it is more convenient to divide column 3 into two, and put all the positive deviations into one column and all the negative in the other.

upon that portion of algebra known as the theory of probability. As a result of working on this, it has been ascertained that a very fair test as to the real or apparent dependence of one set of observations upon another is afforded by a factor called the *probable error*.[1] If r be the correlation coefficient and n the number of the observations (20 in the case under review) then its probable error has been found to be $= 0{\cdot}674\frac{1-r^2}{\sqrt{n}}$

It will be observed that this factor depends not only on r (*i.e.* the greater is r the greater is the probability of a real connection), but also on n, and as this is in the denominator, it results that the probable error is greater according as n is smaller. In other words the results obtained from only a few observations are not nearly so trustworthy as those from a large number. This is, of course, only in accordance with common sense.

I do not know whether I can convey any good idea of the principle underlying the notion of the probable error. You doubtless all know that if we toss a coin for a very large number of times, heads and tails will turn up about equally often in the long run. If we toss for a thousand times, however, we shall almost certainly not get *exactly* 500 heads and 500 tails: we should get somewhere near those figures, and we should be very much surprised if we got 600 heads and only 400 tails. So great a difference as a proportion of 3 : 2 is very unlikely to occur, and if it did occur we should suspect very strongly that the tosser was able to exercise some (perhaps small) influence over the coin. Yet if we only toss five times, the nearest approach to equality that we can possibly get is 3 : 2; and if we toss ten times we are almost as likely to get 6 : 4 as 5 : 5. Thus a distinct inequality in the case of a small number of observations is of no significance, whereas it is important in the case of a large number. Similarly a distinct correlation coefficient is no evidence of connection if the number of observations be small, but the same figure is if they be numerous. With a given coefficient, and a knowledge of the number of observations on which it is based, the probability of its being a true connection can always be calculated, and the "probable error" has been found to be the most useful guide. In practice it has been found *absolutely* safe to say that there is certainly a connection between two phenomena if the correlation coefficient be at least six times its probable error. This represents odds of many thousands to one in favour of the connection being real. In the example above, the probable error is 0·09, which is less than $\frac{r}{6}$, and hence we may safely conclude that the rainfall of the period is an important factor in determining the depth of water in the well at the end of August.

Perhaps another example regarding probability may be cited as an illustration. It is well known that the bank at Monte Carlo "always" wins, and that a very steady revenue is derived therefrom. Yet it would seem, to judge by the rules of the play, that the odds in favour of the bank are only very slight. Slight as they appear, however, they tell in the long run, owing to the large number of times the game is played. But still it is not really an absolute certainty; a particular individual may

[1] This term does not mean that the coefficient is probably wrong by the amount of the "probable error," but that in a long series of such coefficients, differences from the mean value greater and less than the probable error are equally likely to occur.

upon occasion "break the bank," and therefore it is quite conceivable that such an operation may occur so frequently that the bank will have lost by the end of the year. With a correlation coefficient six times its probable error, the chances of there being no connection are far more remote than those of a given individual breaking the bank at Monte Carlo.

Thus, whatever the correlation coefficient (if not unity) there is always a remote chance—it may be many millions to one—that the connection is accidental. But it is always strictly true that the coefficient measures the resemblance that has actually held for the observations included in the calculations. It is only when we want to know whether the connection is causal, and, as a corollary, whether it will still hold in the future, that we have to consider questions of probability. And it may

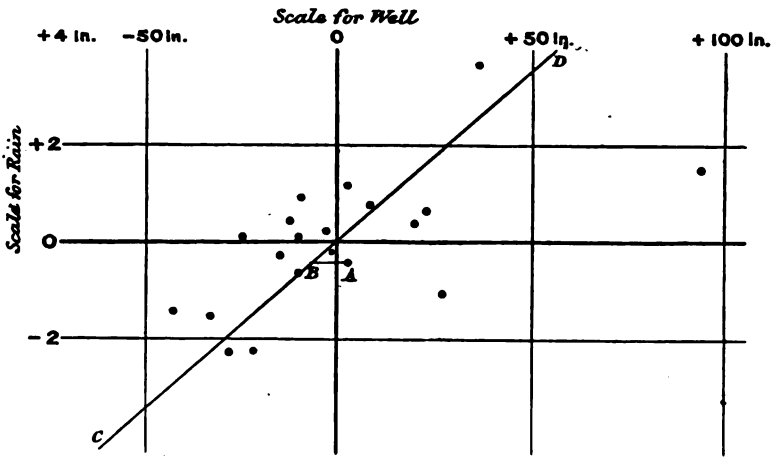


FIG. 2.

perhaps not be amiss to remark that when a writer points out, as frequently occurs, that "inspection of the diagram shows that ups and downs correspond fairly, and therefore the two sets of phenomena are interdependent," such a writer has frequently quite small odds in his favour.

Now let us examine the same set of figures in a different manner. Take some squared paper, and draw a horizontal line, about the middle of the paper, and a vertical line, also about the middle. We have now divided the paper into four compartments. Make a vertical scale on one side to represent deviations of the rainfall from the mean, putting O at the horizontal line, all deviations above the line being positive, and those below negative, and the range being great enough to cover all the deviations in col. 3 of our correlation table. Similarly make a horizontal scale for the well-depth, the central vertical line representing O: we will put positive deviations to the right and negative to the left.[1] The squared paper can now be used to plot corresponding deviations of both rainfall

[1] In the example given here the vertical scale has been made twelve and a half times the horizontal, so as to exhibit the features better.

and well-depth by means of single dots. Take the first year, 1887, for instance; we have a rainfall 0·4 in. below the average, and a well-depth 3 in. above: I therefore put a dot at a distance 0·4 *below* the horizontal line, and 3 to the *right* of the vertical line. This is the dot marked A. Similarly for all the other years, so that I have a diagram, (Fig. 2) with 20 dots on it.

It will be observed that most of the dots—at least those that are remote from the centre—fall in the upper right-hand compartment, or in the lower left-hand compartment, comparatively few being in the other two compartments; moreover, when a dot is far from one central line, it is not very near to the other. In fact, the dots are not distributed haphazard, but have a tendency to approach a line, or to lie in a belt, running through the centre of the diagram from one corner to the other. I have drawn a straight line (CD) upon the diagram with the following property, viz.: that if we draw horizontals from all the dots to it, then the sum of the squares of all these horizontals is a minimum, that is, the sum of the squares of lengths such as AB is a minimum. Those who have studied analytical geometry know that a line can be expressed by an equation: the equation to CD is $x = \frac{\sigma_x}{\sigma_y} ry$, where σ_x, σ_y and r have the same meaning as before.

For, let the equation to the line CD be $x = \lambda y$, and let $x_1 y_1$ be the ordinate of the point A, thus $AB = x_1 - \lambda y_1$

$$AB^2 = x_1^2 - 2\lambda x_1 y_1 + \lambda^2 y_2^2$$
$$\Sigma(AB^2) = \Sigma x_1^2 - 2\lambda\Sigma(x_1 y_1) + \Sigma(\lambda^2 y_1^2)$$
$$= n\sigma_x^2 - 2n\sigma_x\sigma_y\lambda r + n\lambda^2\sigma_y^2$$
$$= (n\sigma_x^2 - 2\lambda\sigma_x\sigma_y r + \lambda^2\sigma_y^2)$$

To find the minimum value of the expression in brackets, differentiate with regard to λ and equate to 0, then

$$-2\sigma_x\sigma_y r + 2\lambda\sigma_y^2 = 0 \text{ when } \lambda = \frac{\sigma_x}{\sigma_y} r.$$

Hence $\Sigma(AB^2)$ is a minimum when the equation to the line is $x = \frac{\sigma_x}{\sigma_y} ry$.

In this example $x = 14{\cdot}3y$.

Thus what we have been doing in calculating the correlation coefficient really amounts to finding a straight line along which the observations, plotted in this manner, tend to group themselves. And this points a warning: the observations might not tend to approach a straight line, but some other curve; in which event the correlation coefficient is not the best indicator of the connection between the two sets of observations, and to find the true relationship becomes a much more complicated task. It is always as well, therefore, to plot such a "dot-diagram" as the above, in order to see that the relationship is not of a peculiar type. In such a case the correlation coefficient between simple deviations from the average might not show a relationship. The converse, however, does not hold, for if the correlation coefficient is significant, a relationship always exists.

It is evident that a second line can be drawn so as to make the sum of the squares of the *verticals* from the dots to it a minimum: its equation

is $y = \frac{\sigma_y}{\sigma_x} rx$. The two lines are known as the *regression*[1] *lines*, and the equations may be called the regression equations. They can be made of great practical use—more especially if r be large—since they give the approximate value of y corresponding to a given value of x, *i.e.*, in this instance they enable us to forecast, within certain limits, the depth of water there will be in the well in August from the spring rainfall. It is to be carefully remembered, however, that the forecast will rarely give the exact amount: it only gives an average of the depths corresponding to the given rainfall. In fact, the forecast *is* a kind of average, and it is no more safe to pin our faith to its accuracy in a given year than it is to pin our faith to the rainfall of next June being exactly the average. Inspection of the above "dot-diagram" shows that all the dots lie within a belt running transversely across the paper, and it may be safely forecasted that for a given rainfall the well-depth will lie on that part of the vertical corresponding to the rainfall which is within the belt. For instance, given a rainfall 2 inches above the mean in the 13th-20th weeks, the regression equation forecasts a well-depth of 57 inches above the mean, and it is practically a certainty that it will not be below the mean, and not more than 100 inches above it at the end of August.

It should be noticed that, if we wish to estimate what was the rainfall corresponding to a given depth, we should use the other regression equation. If the one phenomenon depended *absolutely* on the other, then r would, as already stated, be unity, and the two "regression lines" would coincide.

We have found in this case a correlation coefficient of + 0·63. This is not unity, therefore the rainfall of the 13th-20th weeks is not the sole cause of the amount of water in the well. There are other causes, and several of these have been briefly discussed in my brother's papers. Three special cases may be noticed in the second diagram, in two of which the dots are unusually far from the regression line. The farthest of all is 1888. If we refer to the diagrams in my brother's first paper, we shall notice that the heavy rainfall at the end of July and the beginning of August in that year actually succeeded in penetrating to the well and adding 8 ft. of water to it—"a very unusual circumstance." This is an excellent illustration of what I want to bring out, viz., that the method of correlation measures the average dependence during the whole period of the observations. In that *particular* year July-August was certainly the dominant factor, but over the *twenty* years it was not. The 13th-20th weeks were of some importance in that year, but happened to be subordinated to the summer: "a very unusual circumstance." Note that this is fully taken into account in the correlation coefficient: were 1888 omitted, the coefficient would have been different.

The second special year is 1903, in which (otherwise wet) year the very dry July seems to have pulled the well down almost abnormally. But on looking at my first diagram, careful inspection gives rise to the suspicion that there is a tendency for the level of the water in the well to be gradually reduced, *i.e.*, that owing to some cause, possibly more general drainage or other depletion of our underground water supplies,

[1] This term was introduced by Mr. F. Galton in discussing heredity, and is expressive in connection with that science.

a given rainfall does not result in so much being stored up as twenty years ago. The diagram merely allows us to suspect this, and points to the desirability of confirmative investigation in other directions. If there is a tendency towards a reduction of the average well-depth our regression line should be really not quite a straight line; although for the crude purpose we require, and in view of the small number of years' observations, a result obtained allowing for this factor would differ so slightly from ours as to be negligible.

The third case is the outlying dot in the lower right-hand compartment. This is 1891, when the well was filled in May, having been at a very low level at the beginning of March. This is the year in which, thanks to May, and in some degree also to a wet summer following, Mr. Symons's forecast was so badly thrown out. The winter was the driest of the twenty years, but at the end of the fourth week of August there was actually more water in the well than in any other of the twenty years.

Summing up what has gone before, it may be said that such simple correlation measures the effect of differences from the mean in one phenomenon upon differences from the mean in another, eliminating other factors affecting them; in fact, after making allowances for the causes which pull the dots away from the straight line in the "dot-diagram" above.

The particular problem set can now be solved quite shortly. I have found a connection, indicated by a coefficient of $+0{\cdot}63$, between the well-depth at the end of August and the rainfall of the 13th-20th weeks. What is the coefficient with the winter rainfall? The various winter rainfalls at the same spot—*i.e.*, the rainfalls of October to March—are given in my brother's papers. I correlate them in exactly the same way with the well-depth, and find a coefficient of $-0{\cdot}11$. That is to say, that a heavy winter rainfall tended, if anything, to be followed by a deficiency in the well! But the probable error of so small a coefficient is considerable, viz. $0{\cdot}15$; and it may therefore most certainly be said that the connection is only apparent, and that the depth of the well at the end of August does not depend in any degree whatever upon the winter rainfall. This proves my brother's conclusion that any surplus water which falls in the autumn and early winter has long since reached the sea, and is not available in summer.

If we compare winter rainfall with the well-depth by means of diagrams, we shall find that by plotting the data in the same way as in my first diagram, the ups and downs of the curves by no means correspond. Or if we plot a "dot-diagram," the dots are scattered all over it, and there is no tendency to lie in a belt. A correlation coefficient of practically zero is the mathematical expression of this haphazard distribution.

Correlation also permits of our finding *which* is the most important period, with a little trouble. To do this, it is only necessary to correlate the well-depth successively with different periods. I have done this for the 1st-8th, 5th-12th, 9th-16th, . . . 25th-36th weeks. Of course, the rainfall of the 5th-12th weeks, which overlaps the first period, is partly dependent on it, and therefore if we find a significant coefficient with each period, we cannot say that the well is dependent upon both. Similarly it is quite conceivable that the rainfall of January is connected

with that of April, and we cannot treat all our correlation coefficients as necessarily independent of each other; *i.e.*, in the latter case a connection with April might be due to the similarity of the January and April rainfalls, and the well might really depend upon January. But it *will* be true to say that the well-depth is most connected with the rainfall of that period with which we get the maximum coefficient; and this I propose to ascertain. The correlation coefficients are as follows:—

Period: Weeks	1st-8th.	5th-12th.	9th-16th.	13th-20th.	17th-24th.	21th-28th.	25th-32nd.
r	−0·28	+0·02	+0·35	+0·63	+0·50	+0·28	+0·42
Probable error	0·14	0·15	0·13	0·09	0·11	0·14	0·12

The maximum is + 0·63, and the 13th-20th weeks (*i.e.*, end of March to middle of May) are therefore the most important of the periods examined. The connection with 9th-16th weeks and with the 17th-24th weeks is obviously due partially to the overlapping of these with the maximum period. It will be noticed, moreover, that all the probable errors, in the case of the other periods, are greater than $\frac{r}{6}$; hence we are not able to say, with absolute certainty, that the well-depth is, normally, dependent upon any of them. Still it is probable that every month after March has, upon a certain few occasions if not regularly, exercised some influence upon the well. I notice that the coefficient of the 17th-24th weeks is greater than that of the 9th-16th weeks, hence I conclude that there is a distinct probability that a period a little later than the 13th-20th weeks—say perhaps the 14th-21st weeks (*i.e.*, April-May)—is the most influential on an average of years. This is even a shade later than my brother puts it. It may possibly be the case that a wet May is only of importance when April has been sufficiently damp to allow the May rains to percolate, and if so it may be said that April was the most critical time even in such years, although its rainfall may have differed but slightly from the average. Such a statement, however, does not seem to lend itself to treatment by the method of correlation, and is neither proved nor disproved by it.

It may be added that by taking periods of a somewhat different duration, says six weeks, or ten weeks, etc., it is possible that we might light upon a somewhat higher coefficient, but the broad statement made above is sufficiently accurate under the circumstances.

DISCUSSION.

THE PRESIDENT thanked Mr. Hooker for his explanation of a very important method of dealing with statistics. In inviting discussion of the paper he wished to remind the Fellows that the object of the paper was the method; and as the facts had already been discussed when the original papers were read, he trusted that the discussion would refer to the method and not to the illustrations.

Dr. W. N. SHAW remarked that the paper brought before the Society for the first time a method which was now applied in many statistical sciences, and had recently been practised by the Director-General of Indian Observatories to measure the correlation between pressures in different parts of the world, and so to form the basis of a numerical statistical method of forecasting seasons in India. It was important that the Society should take account of this method of correla-

tion. He had spoken of it before the University of London in a lecture, but this had not been published, and he was glad that Mr. Hooker had brought the subject forward again. He did not altogether share Mr. Hooker's opinion as to the extent of its superiority over the diagrammatical method of comparison. It was certainly quite possible to deceive oneself in comparing two curves on a diagram. But on the other hand the correlation method, as described, was applicable only to cases having a linear proportion between the two quantities compared. He would like to know what would happen if one had to deal with a number of observations from two anemometers, one recording the pressure, and the other the velocity. There should be a correlation between them, as the wind force was known to be proportional to the square of the wind velocity. Diagrammatically correlation would be indicated because the elevations on one diagram would be proportional to the square of the elevations on the other. Another point was that, supposing the quantities measured depended upon two independent variables, how would that be represented in the correlation coefficient? He congratulated Mr. Hooker upon his paper, and thought the Fellows should realise the advantages of using this method in their own work.

Mr. R. H. HOOKER, in reply, said that when the relationship between two phenomena was not linear, they had to look very carefully at the results, and also consider very carefully *what* should be correlated. Simple correlation was frequently inapplicable, and higher mathematics might be required to bring out the true connection. On the other hand, various devices could in many cases be employed, *e.g.*, he had himself correlated the oscillations of the marriage rate and trade by correlating, not differences from the mean, but differences from the trend of the curve, *i.e.* from a variable average. He thanked them for the kind way in which they had received the paper.

THE PRESIDENT said that the paper read by Mr. Hooker had been put forward in a very clear and pleasing manner. He hoped that when the paper was printed Mr. Hooker would add an appendix giving the rigid definitions of the terms used, and also of other terms which he had avoided in simplifying his paper, but which ought to be put on record in a form convenient for Fellows of the Society to refer to. He thanked him for his kindness in bringing this important subject before them.

Teaching of Meteorology at Agricultural Institutions.

The President of the Board of Agriculture and Fisheries in the early part of 1907 appointed a Departmental Committee, "to enquire as to the provision which has now been made for affording scientific and technical instruction in agriculture in England and Wales, and to report whether, in view of the practical results which have already been obtained, the existing facilities for the purpose are satisfactory and sufficient, and, if not, in what manner they may with advantage be modified or extended." The Report of this Committee has just been published as a Blue Book. In dealing with the teaching of Meteorology at Agricultural Institutions, the Committee report as follows :—

"The attention of the Committee was drawn to this subject as one which, up to the present time, has received but little attention in this country.

"Dr. H. R. Mill, President of the Royal Meteorological Society, pointed out that the Meteorological Office has amongst its other duties that of preparing reports and weather forecasts for the British Isles, and that he was afraid that a very large number of farmers are not able to profit by this expenditure of public money on their behalf, because of their inability to understand the Weekly Weather Report.

"Dr. Mill holds that 'imparting a knowledge of the methods of meteorology is technical instruction in agriculture to this extent, that it helps a farmer to decide difficult questions that arise occasionally as to whether he should proceed with a certain agricultural operation in certain conditions of weather, or whether there are sufficient data before him in the published reports, say, of the Meteorological Office, to justify him in postponing it on the ground that better weather is coming.'

"The Committee are of opinion that in agricultural and horticultural institutions, provision might well be made for instruction which would enable farmers and gardeners to make use of existing means of information regarding the weather, and direct farmers' attention to the relations between meteorology and the crops."

Prize Competition of the German Meteorological Society.

Dr. G. Hellmann, the President, has informed us that the German Meteorological Society offers a Prize of three thousand Marks for the best discussion of the meteorological results obtained in the International Kite and Balloon Ascents. The conditions are:—

1. The judges are free to divide the prize.
2. Persons of any nationality may take part in the competition.
3. The communications may be in German, English, or French, and must be well and legibly written on one side of the paper only, and further have a Motto attached. They must be accompanied by a sealed envelope, bearing on the outside the same Motto, and containing inside the name and address of the sender.
4. The latest date for sending in will be December 31, 1911, and communications should be forwarded to Dr. G. Hellmann, Berlin W. 56, Schinkelplatz 6.
5. The results of the competition, as decided by five judges, will be made known in 1912 in the *Meteorologische Zeitschrift*.

Lectures on Meteorology.

Mr. E. Gold will give a course of Lectures in Meteorology at the Cavendish Laboratory, Cambridge, during the Michaelmas term, on Thursdays at 5 p.m., beginning on October 15. The syllabus is as follows:—

Variation of meteorological elements over the surface of the earth. Temperature, pressure, and wind. Comparison with theory. Humidity and rainfall. Cloud and duration of sunshine.

Periodic changes in pressure, temperature, etc. (1) Diurnal, semi-diurnal. Connection between pressure, wind, and temperature variations. (2) Annual. Irregularities in annual temperature curve. (3) Newcomb's investigation of temperature changes of long period. (4) Brückner's 35 year period. Lockyer's Barometric See-saw. Moon-period in thunder-storm frequency.

The relation of pressure gradient to wind velocity. Characteristic difference between cyclonic and anti-cyclonic motion. Motion of the air in cyclonic depressions and line-squalls according to Shaw and Lempfert.

Investigation of the upper air. Results of kite ascents.

The isothermal layer: its bearing on the general circulation.

Correlation. Applications to pressure by Lee and Pearson and Cave-Brown-Cave. Application to rainfall, temperature, and crops by Hooker.

Telegraphic meteorology and forecasting. Abercromby's types of pressure distribution. Guilbert's rules. Ekholms' isallobars.

THE HONGKONG TYPHOON, SEPTEMBER 18, 1906.

By LAWRENCE GIBBS, F.R.Met.Soc., Assoc.M.Inst.C.E.

[Read June 17, 1908.]

THE typhoons of the China and Eastern seas usually have their origin in the Pacific to the eastward of the Philippine Islands; they occur during every month of the year, but are of rare occurrence during the late winter and early spring.

In point of view of the direction taken, they may be roughly divided into three classes. Those of the first class take westerly or north-westerly courses across the Philippine Islands and the China Sea, and reach the coast of Asia between Saigon and Shanghai. Those of the second class, after first moving westward, "recurve," before reaching the Philippines, and travel to the north and north-east, usually passing up the Japanese Islands. A third class includes those few which follow courses intermediate between, or outside of these.

They have been studied for many years at the Observatories of Manila, Zi-ka-wei (Shanghai), Hongkong, and Tokio, and on the publications of these Observatories most of the information given in this paper is based.

They are found to vary greatly in size, intensity, rate of progress, and direction.

Size.—The typhoons experienced in Hongkong on July 29, 1896, and September 18, 1906, may be taken as extremes in size. During the former a velocity of 108 miles (old constant 3) in an hour was recorded at the Observatory when the centre of the typhoon was 47 miles (nautical) distant; while a mean of several observations at sea gave wind force 6 at 230 miles from the centre. In the latter, force 6 only was experienced at the Gap Rock lighthouse, 32 miles south-west of Hongkong Observatory and 38 miles distant from the centre, and a velocity of 24 miles in an hour was registered in Hongkong $2\frac{1}{2}$ hours before the typhoon centre reached the Colony and when it was only about 30 miles distant. If wind force 6 be taken as the limit, then the 1896 typhoon would be about 500 miles diameter, and the 1906 typhoon less than 100 miles diameter.

Intensity.—The barometric gradient, which is a general, though not an absolute guide to the wind force, often exceeds ·20 inch in 15 miles near the centre of a typhoon; but during the typhoon season shallow depressions are of common occurrence, and these in traversing the China seas often deepen and become regular typhoons. The converse also occurs, a well-defined typhoon sometimes partially "filling up" and becoming a shallow depression. It thus becomes a question of degree what is a typhoon and what is not, and no lower limit other than an arbitrary one can be fixed to the gradient in a typhoon.

Rate of Progress.—This varies mainly with the time of year and the latitude; generally the winter typhoons are slower, and those traversing high latitudes quicker, than the average. The typhoons which cross the Philippines between May and October travel at from

8 to 12 miles an hour; but in different latitudes and at other times of the year they have been known to travel at from 3 to 30 miles an hour.

Direction.—Fig. 1 shows the tracks of the principal typhoons of 1905 as computed by Mr. F. G. Figg of the Hongkong Observatory.

In view of the considerable area usually covered by a typhoon and their frequent occurrence during the season, there was nothing peculiar in the fact that one should pass close to Hongkong. But the fact which brought the typhoon of September 18, 1906, into such prominence

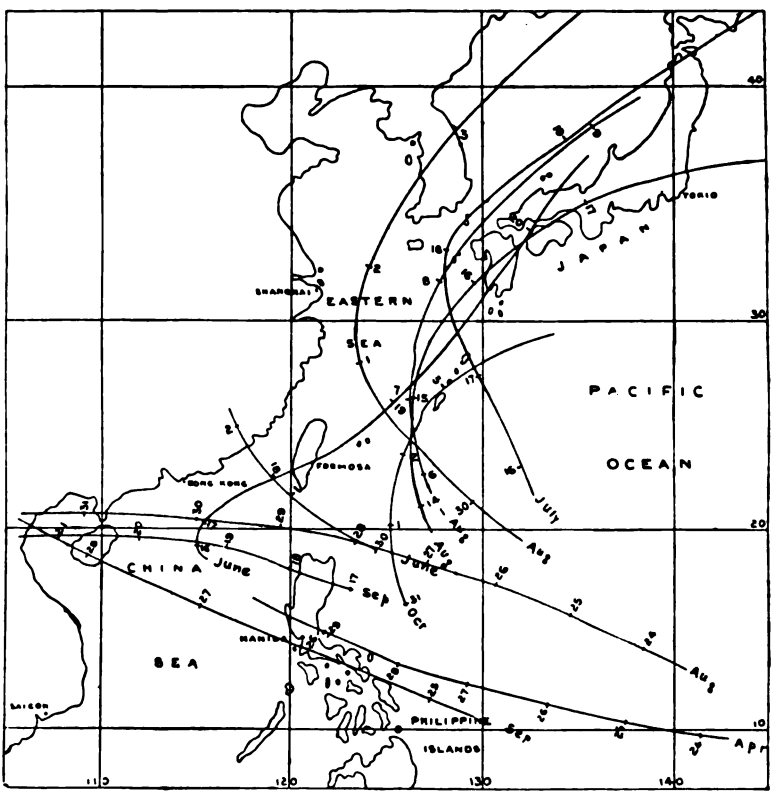


FIG. 1.—Typhoons of 1905.

was the failure of the Observatories to give any adequate warning, and the consequent heavy damage to shipping and small craft. This loss was accentuated by the fact that the typhoon centre passed to the north of the harbour, thus causing a North-westerly backing to Southerly gale. The harbour, as will be seen from Fig. 2, is much less sheltered from the west than from any other quarter.

Judged by anemometer records the typhoon was by no means a severe one. The records are from a Robinson cup anemometer, and the figures available only give the hour's velocity and take no account of the heavy squalls of short duration, which are so distinct a feature in typhoons. Indeed, from the published returns it appears that the highest average

hourly wind velocity was 77 miles—it never reached what is known as typhoon force or 80 miles per hour. During the 23 years 1884-1906, this velocity has been exceeded on seven separate occasions, totalling 20 hours, at the Hongkong Observatory, the maximum being 108 miles per hour. The small amount of damage done on shore confirms the conclusion thus reached.

In the harbour, 45 merchant vessels of an aggregate tonnage of 46,994 were either badly injured, stranded, or foundered, 80 steam launches out of a total of 256 were permanently or temporarily disabled,

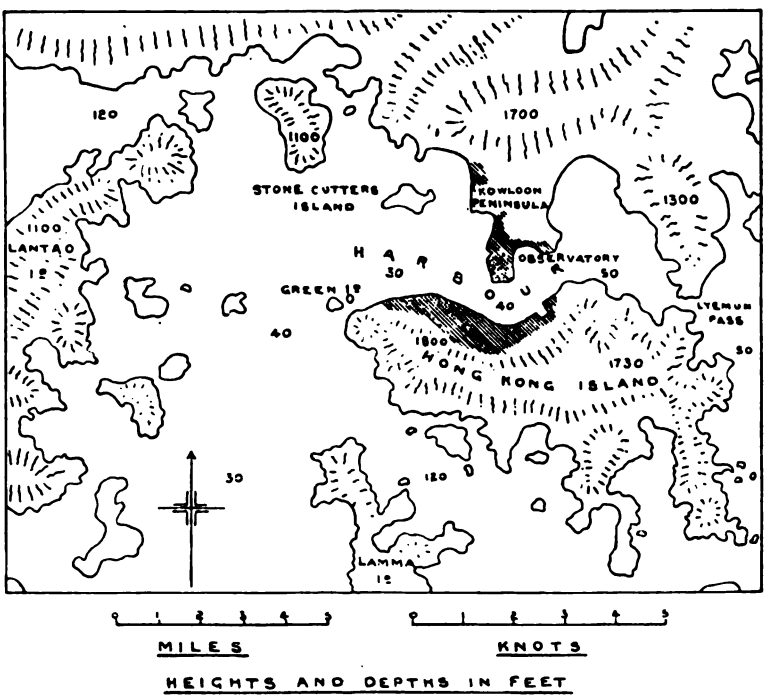


FIG. 2.—Hongkong Harbour.

and a great number of lighters, junks, and small craft broken up. Sixteen Europeans lost their lives, 2385 Chinese were reported missing, but as in many cases the whole family lived on the boat, and as many boats were lost with all hands, it is probable that this figure was considerably exceeded.

The Observatory at Zi-ka-wei came more nearly than any other to an adequate forecast.

It issued the following notices:—

September 15.—"A new centre" (*i.e.* of low pressure) "is signalled advancing towards Formosa from the south of the Meiaco Sima Group."

September 16.—"The centre in the south is nearly stationary at Formosa."

September 17.—"The one reported at Formosa fills up gradually."

September 18.—"A very violent storm of quite limited area raged in Hongkong on Tuesday morning" (*i.e.* September 18).

The Philippines Weather Bureau issued a Bulletin dated October 10, 1906, in which it gave the probable track (Fig. 3) of the typhoon from 140° east. It was enabled to do this by observations received from vessels at sea in the neighbourhood of the typhoon, and from a report received from the Observatory at Santo Domingo, a station not connected by telegraph with Manila. These observations were considered to

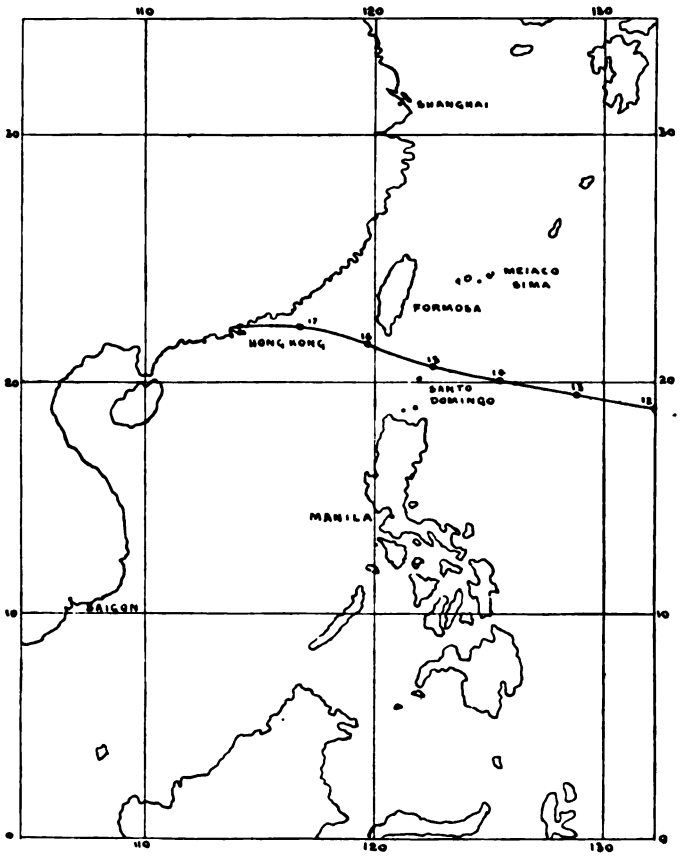


FIG. 3.—Track of Typhoon, September 1906.

corroborate the Zi-ka-wei deductions of the 15th and 16th. As, however, they were only available after September 18, the Manila Observatory was unfortunately not in a position to give any forecast of the typhoon.

The Hongkong Observatory did not consider the observations available on the 16th and 17th justified the issue of any typhoon warnings, and at 11.35 a.m. on the latter date issued the following forecast for the 24 hours ending noon on the 18th:

"Hongkong and neighbourhood.—Variable winds, moderate; probably some thunder showers."

At 8 a.m., however, on the morning of the 18th, it was found that the barometer was falling rapidly, and the weather appearing threatening,

orders were given to hoist the Black Drum—the weather signal indicating that there was a typhoon within 300 miles to the eastward of the Colony—and at 8.40 a.m. the typhoon gun was fired, indicating that a strong gale of wind was expected to blow. This was only about an hour before the storm was at its worst. It will thus be seen that, though it seems highly probable that Zi-ka-wei located the typhoon fairly closely on September 15 and 16, it did not actually describe it as a typhoon, and lost sight of it after the latter date; and on the 17th, when the storm was advancing directly towards Hongkong, reported it as filling up.

There is no doubt it was the small area covered by this typhoon which caused this failure of the forecasts. This small area is shown in several ways. As has been already stated at the Gap Rock lighthouse, 38 miles from the centre, wind force 6 only was noted. At Macao, 35 miles west, and at Canton, 75 miles north-west of Hongkong, only a slight storm was experienced. Assuming that the rate of travel of two typhoons is about the same, which is approximately the case in the same latitude and season, then the time they take to pass is a fair test of their relative size, if they are equally distant from the observing station. In the typhoon of September 18, 1906, the wind was at 50 miles per hour and over for only 3 hours, with the centre only 6 miles distant. While in the typhoon of October 5, 1894, it blew at over 50 miles per hour for 29 hours; and in the typhoon of July 29, 1896, whose centre passed at 47 miles from the Observatory, 50 miles per hour was registered for 10 hours.

The following table gives the observations of barometer, temperature, rain, and wind at the Hongkong Observatory on September 18, 1906 :—

OBSERVATIONS TAKEN AT HONGKONG OBSERVATORY, SEPTEMBER 18, 1906.

Hour.	Barometer.	Temperature.	Rain.	Wind.	
				Direction in points. 32 is north.	Velocity in miles.
	Ins.	°	In.		
1 a.m.	29·685	78·8	...	27	8
2 ,,	·666	79·0	...	25	7
3 ,,	·661	79·0	...	29	10
4 ,,	·636	79·1	...	27	12
5 ,,	·621	78·6	...	29	15
6 ,,	·602	78·4	...	28	14
7 ,,	·584	77·3	·29	27	24
8 ,,	·493	76·8	·13	28	43
9 ,,	·119	74·5	·81	27	73
10 ,,	·066	75·0	1·25	18	77
11 ,,	·493	75·6	·90	16	50
Noon	·590	77·1	·40	18	31
1 p.m.	·645	78·5	·15	15	20
2 ,,	·661	79·4	·05	15	21
3 ,,	·679	80·3	...	14	18
4 ,,	·675	81·9	...	14	15
5 ,,	·681	80·7	...	12	14
6 ,,	·691	79·5	...	9	21
7 ,,	·716	79·5	...	11	21
8 ,,	·755	78·0	·41	11	21
9 ,,	·784	77·7	·17	11	16
10 ,,	·794	79·9	...	9	25
11 ,,	·791	79·5	...	10	22
Midnight	·778	79·8	...	10	28

Fig. 4 gives the barograms for three typhoons which have passed near to Hongkong, and shows how short the warning given by the barometer was on September 18.

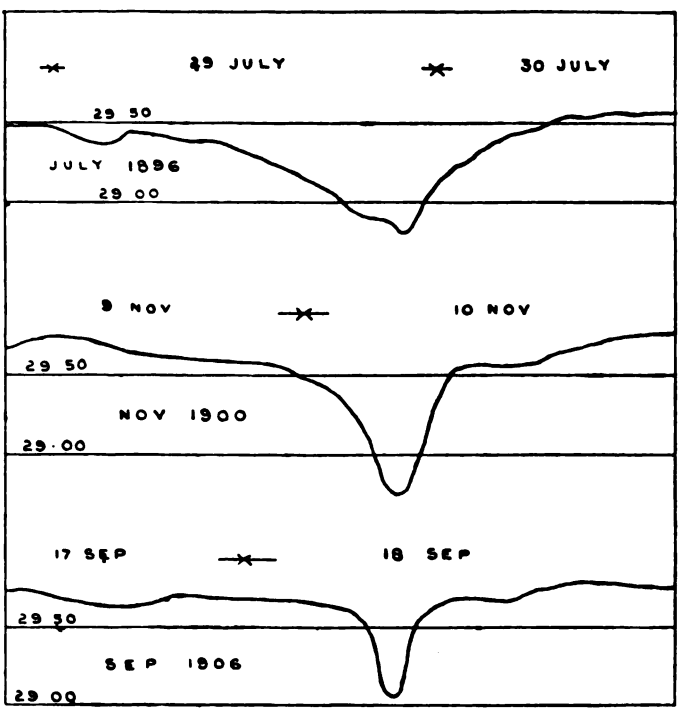


FIG. 4.—Typhoon Barograms in Hongkong.
Plotted from Hourly Readings at Hongkong Observatory.

DISCUSSION

Mr. F. CAMPBELL BAYARD said that with reference to this typhoon, his second son was mate on board the S.S. *Ras Dara*, and he had written him a letter on October 10, 1906, from Ke Lung, Formosa, in which he said :—

"We arrived at Hong-kong last Saturday, October 6, at 8 a.m., and all looking forward for a quiet day the following day. But on our arrival there we learnt of the terrible typhoon that had visited Hong-kong. The Admiralty informed us that we must proceed to Wei-hai-wei, as there was no means of discharging our cargo in Hong-kong, the lighters all having sunk. Well, after taking on board fresh provisions, and the old man doing his business on shore, we hove up the anchor and proceeded, all with sad hearts. As soon as we got outside the harbour the sky was as black as ink, so we thought we should get a typhoon, as four had taken place in the last twelve days. However we didn't, but we *had* a strong North-east gale right up to here. It was so bad that we had to ease our engines for 24 hours. However it can't last much longer now, so we are looking forward now for fine weather."

His son had brought home with him a book with numerous photographs of

the typhoon effects. It was very interesting, giving pictures of the vessels on shore. In a letter to his mother of the same date, his son had said :—

"We arrived here safely to-day at 1 p.m. for bunkers, but find we can't get any (coal) till to-morrow, so we are having a quiet night anchored in Ke Lung Harbour. We got to Hong-kong last Saturday, October 6, but got orders from the Admiralty to proceed to Wei-hai-wei to discharge. Apparently the typhoon was terrible in Hong-kong, as the report there was that 10,000 lives had been lost. Of course that was not Hong-kong alone. The shipping that was affected was chiefly coasting steamers. A vessel of this size could ride it out all right. During the typhoon we were having light variable winds and calms. Pretty well all the ships in Hong-kong Harbour went ashore, but only one sank, and that was a river steamer."

THE PRESIDENT remarked that this typhoon had been a very serious matter, not only because of the damage it did, but also because it threatened the reputation of the Observatory. The omission of an early warning was indeed considered to be so serious that a Government Commission was appointed to investigate the matter. They took a great deal of evidence, which was carefully discussed, and they finally issued a report entirely exonerating the Observatory.

He thanked the author of the paper, and also Mr. Bayard for reading it and for his remarks. This was the last meeting of the Society for the session. They would meet again in November, he hoped, in the hospitable Hall of the Institution of Civil Engineers.

Cones formed by Melting Snow.

Examples of a peculiar surface form, due in part to the melting of snow, are described from Iceland and the Alps respectively by Herr Spethmann and Professor Brückner in the *Zeitschrift fur Gletscherkunde*, vol. ii. pt. 4. The resemblance of the fields of snow cones, of which photographs are given, to the "nieve penitente" of tropical regions is sufficiently great to suggest a similar origin, though this is not pressed by either of the writers ; in fact, Herr Spethmann considers the phenomenon in Iceland to be not entirely analogous with that in the Alps even. The fields which he observed during his recent expedition to Iceland consisted of cones varying in height from half an inch to about 18 ins., and were covered with a layer of volcanic dust, etc., which quite concealed the consolidated snow beneath. They occurred on level or gently sloping ground, and appeared to be in no way dependent on the orientation of the latter. The angle of slope of the individual cones sometimes reached 45°. From the fact that, where not covered with earthy matter, the snow showed few, if any, irregularities, Herr Spethmann concludes that the cone formation is entirely due to the deposition of the dust by the wind and the development on its surface of ripple marks which lead to a differential melting of the snow beneath. Professor Brückner's example is from the Rhone glacier, and shows equally the effect of an original ripple-marking of a layer of dust above the snow.—*Geographical Journal*, September 1908.

DINNER OF THE ROYAL METEOROLOGICAL SOCIETY.

The Annual Dinner of the Society was held at the Trocodero Restaurant, Piccadilly, on Tuesday evening, June 16, 1908.

The President, Dr. H. R. MILL, was in the chair, and the company included the following Fellows and guests.

Mr. E. B. BARNARD, M.P.
Mr. F. CAMPBELL BAYARD.
Mr. CLAYTON BEADLE.
Mr. A. BOYLE.
Mr. F. J. BRODIE.
Mr. A. H. BROWN.
Mr. ERIC S. BRUCE.
Capt. W. F. CABORNE, C.B.
Mr. C. J. P. CAVE.
Mr. J. E. CLARK.
Capt. M. H. CLARKE.
Capt. R. MUIRHEAD COLLINS, C.M.G.
Mr. R. COOKE.
Mr. J. A. CURTIS.
Dr. G. F. DEACON.
Mr. F. DRUCE.
Mr. F. B. EDMONDS.
Rev. W. ESDAILE.
Mr. H. N. FFARINGTON.
Rev. J. C. FOX.
Dr. LEEDHAM H. FULLER.
Mr. W. V. GRAHAM.
Mr. C. HAWKSLEY.
Col. R. C. HELLARD, C.B.
Dr. A. J. HERBERTSON.
Rev. H. N. HUTCHINSON.
Mr. R. INWARDS.
Mr. A. P. JENKIN.
Dr. J. SCOTT KELTIE.
Mr. BALDWIN LATHAM.
Mr. G. B. LATHAM.
Mr. R. G. K. LEMPFERT.
Dr. E. LEWYS LLOYD.
Capt. H. G. LYONS, F.R.S.
Mr. W. MARRIOTT.
Mr. W. J. MARRIOTT.
Dr. J. D. M'CLURE.
Mr. R. MOND.
Mr. R. W. MUNRO.
Mr. P. P. PENNANT.
Mr. C. SALTER.
Mr. W. SEDGWICK.
Sir J. BENJAMIN STONE, M.P.
Dr. A. STRAHAN, F.R.S.
Mr. G. TALBOT.
Dr. J. J. H. TEALL, F.R.S.
Mr. A. WATT.
Dr. C. THEODORE WILLIAMS.
Representatives of
The Daily Telegraph.
The Morning Post.
The Standard.
The Times.

THE PRESIDENT, in proposing the toast of "The King," said, that the Meteorological Club in one triple toast of six words gave expression to all that on this more formal occasion was expanded into three separate speeches; the sentiment, in expanding, however, was not chilled. When welcoming the President of the French Republic on a recent auspicious occasion, the King—if they were to trust the Press, and if they could not trust the Press, where were they?—first spoke appreciatively of the fine weather. If the King, on such an occasion, spoke first of the weather, then surely the students of the weather at their annual festival should speak first of the King, wishing him long life for his magnificent work as an organiser of peace among the nations, and always the best of weather, as was fitting for the best of Kings.

"God save the King."

THE PRESIDENT, in proposing the toast of "The Queen, the Prince of Wales—Patron of the Royal Meteorological Society—the Princess of Wales, and the other Members of the Royal Family," said that it was their privilege to associate with all such gatherings the names of the Queen and the Royal Family. Every

passing year showed more strongly the warm interest which the Queen took in all matters appertaining to the welfare of the nation and the advancement of science. Their Patron, the Prince of Wales, was preparing to cross the Atlantic to participate in the commemoration of the origin of Canada, and at the same time the Society which he honoured by his patronage, was sending a representative to take part in the first Conference of Meteorologists of the Empire, initated by the Royal Society of Canada, and to be held in Quebec on the 300th anniversary of the Foundation of that city.

"God bless the Prince of Wales."

Dr. C. THEODORE WILLIAMS, in proposing the toast of "The Visitors," said that it was his great privilege to propose this toast. Their visitors were not only great but good, and he would depend upon that goodness for a sympathetic acceptance of his remarks. He could not be expected to give a complete biography of the many guests present. They greatly regretted the unavoidable absence through indisposition of Lord Strathcona, who would otherwise have been the guest of the evening. Lord Strathcona was not an ordinary man; he was a great personality both in Canada and England. He was a broad-minded and true son of the Empire, and a generous supporter of all deserving institutions. Canada was taking a great lead in a new phase of meteorology by her action in summoning the first Imperial Conference, at which the Royal Meteorological Society would be well represented by its President. The next name he had on the list was that of Captain R. Muirhead Collins, who was looking after the interests in this country, of the Commonwealth of Australia. The various States, which were powerful when independent, would be far more so now that they were federated. Australia was the only country that had organised a complete meteorological service, in which one office issued daily forecasts for a whole continent. Sir Benjamin Stone was a great promoter of public enterprises, and was also well known for his photographic work. The Society owed much to photography, for it depended largely upon photography for obtaining many of its records; hail stones, lightning flashes, wonderfully beautiful forms of clouds, and many others. Mr. E. B. Barnard was the head of one of the most important Water enterprises in the world, and, as Chairman of the Metropolitan Water Board, represented a body which was greatly interested in the question of rainfall. Dr. Teall, Col. R. C. Hellard, the Rev. H. N. Hutchinson, Dr. Scott Keltie, Dr. McClure and Dr. Strahan were also referred to. Dr. Theodore Williams then gave the toast of the "Visitors," coupling with it the names of Captain R. Muirhead Collins and Dr. J. D. McClure.

Captain R. MUIRHEAD COLLINS, in replying to the toast, apologised for his intrusion on the Toast List, but said that he must obey the orders of the President. He greatly regretted that Lord Strathcona was not present to respond to the toast. He himself could hardly be classed among the "good and great," as though he might assume the goodness, the greatness was beyond him. On the other hand, as regards the other guests, he could not answer for their goodness, but was assured of their greatness. Australia would look for great things from its Meteorological Service. They relied upon a thorough knowledge of weather conditions of the country to help them in overcoming certain economic difficulties as they arose. Although Canada was in the forefront in bringing the meteorologists of the Empire together, Australia was not behind in its forecasting department, and the fact that Australia was the only great continent that published a daily weather chart had been referred to by the proposer of the toast. Federation had done that for them, and in federating the Meteorological Department it had made a great advance.

Dr. J. D. MCCLURE, replying to the toast in a humorous speech abounding in anecdote, said that he thanked the Society for the privilege of dining with

them. It had been said that the guests were a wonderful lot of people, and he was sure the guests agreed. Such a truth required to be frequently stated. He did not think any of them had been more fortunate than he, for at his table they had agreed that this should not be the last time they four would dine together. When at Cambridge he had been taught that there were three points to be observed in making a speech. First, to spend a few minutes getting to the subject, then another few minutes skating round it, and finally a few minutes in getting away from it, the last being the most difficult of all, but with renewed thanks, he would resume his seat.

PART SONG—"Sweetly blows the Western Wind."

Mr. E. B. BARNARD, M.P. (Chairman of the Metropolitan Water Board), said that the privilege of proposing the toast of the evening—"The Royal Meteorological Society"—fell to his lot. As far as he personally was concerned, it was a novel position for him to be associated with the Society, and he appreciated it with no mock humility. He was well acquainted with the objects and aims of the Society, although he had not previously been associated with them, and even now he had some difficulty in pronouncing the name of the Society clearly; that was not, however, the result of their hospitality! The Body of which he was Chairman had to concern themselves with water when it arrived on the ground, and they took advantage of the statistics prepared by the Society, realising that the real source of their water-supply was the clouds. He understood that the Fellows of the Society discovered facts of great interest regarding the weather, and placed their results before the public. Weather prophets were a reckless race, and the general attitude of the public towards them was that of suspicion. Engineers and geologists walked arm in arm, and the Society's work was of great value to both; it was done unselfishly and ungrudgingly. They were collecting and collating valuable evidence, and doing so honestly and to the best of their ability; giving up their time for the sake of wider knowledge. He found that the Society's figures were generally complete, and the authority he represented knew the value of sizing them up to the best advantage.

THE PRESIDENT said that he had great pleasure in responding to the toast, and he thanked the proposer for his frank and kindly speech, and for the stress he laid on the importance of the practical applications of meteorology, an aspect which, perhaps, was not so often dealt with as it deserved to be.

The Society had prospered in the past year. It bore its fifty-eight years lightly, and was still growing younger in the added strength of new Fellows. It had delighted to honour the distinguished French meteorologist, M. Teisserenc de Bort, with the Symons Gold Medal for his magnificent work in founding the scientific study of the upper air. It had been delighted and honoured by the eminent chief of the Prussian Meteorological Service, Dr. Hellmann, whose unique studies of old records enabled him to expound the Dawn of Meteorology as no one else could, and who pleased them by recalling how prominent a part had been taken by English students of weather even in the middle ages.

During the year the Society had endeavoured to stimulate the study of Meteorology in elementary schools by arranging a prize essay competition on weather and climate for teachers. It was gratifying to find how widely the subject had been taken up, for nearly 200 essays had been received. The Society hoped to base upon these essays a systematic syllabus, and to direct it into fruitful channels. Education in the matter of weather study was necessary for more than school children. Some portions of the daily press were painfully credulous and uncritical in dealing with long-range weather predictions, which were pure guesswork, not worth the while of a scientific man to confute, though not infrequently very confusing to the untrained mind. The Society was

quietly endeavouring to find out the laws which governed the weather, and to this end they were not only studying the occurrences taking place in the air at the surface, but, by means of balloons and kites, they were assisting in obtaining records of what was happening in the upper regions of the atmosphere. The study of the upper air was unquestionably the most promising field of work at the present time, and important results could confidently be expected from it.

While the Society spent much time in forwarding researches which would ultimately benefit the public, their modest light was not set on so high a candlestick as they humbly thought it deserved. They received no assistance from public funds, and he ventured to think that no other London Scientific Society of equal age, of equal numbers, or of equal utility was unprovided with free rooms in a Government building, or at least some subsidy towards its maintenance. They received no recognition either in the way of representation on the Visiting Bodies of such institutions as the Greenwich and Kew Observatories, which were largely devoted to Meteorology, yet similar Societies concerned with other activities of those bodies were represented. They did not complain, though they were conscious of the anomaly; and it was well to state this occasionally, were it only to warn the public not to measure their aims and their solid achievements by the easy, though not always just, standard of official recognition. The aims of all scientific societies were necessarily high, and ought to be sufficing, but it was none the less an incentive to have them recognised. They had, he feared, sometimes allowed their higher aspirations to be forgotten. Perhaps in their earlier history they had not always told the outside world clearly enough that they were not simply laying up a wealth of recorded observations, but they had in view the discussion of the accumulated data in order to lead further. That time, if it ever was, had passed. They recognised, and they did not hesitate to proclaim, that they had before them a problem of immense complexity, a problem subject to the sway of innumerable and almost incalculable influences, not always capable of being dealt with by methods which could be classified under one of the great branches of science. He did not think it was always possible to deal with the problems of meteorology by laboratory, or experimental, methods, which usually involved the pursuit of an isolated clue, and the cutting away or ignoring of disturbing causes, which were really as essential to final result as the single line selected. Physicists, chemists and astronomers, he was almost inclined to suspect, were sometimes apt to misjudge the meteorologist. He feared that at times they even failed to appreciate the essentially scientific character of the work of the student of the forces of Nature as they were exemplified on the land's surface, in the water and in the air.

The title of their Society he might remind them was not limited by any territorial restriction; they were a Royal Society and their immediate sphere included all the King's dominions, although as regards one small branch of their work—the collection of observations—they did not invade the territory of their sister Society of Edinburgh,—in all else they were as circumambient as the air itself, for the whole atmosphere was their parish. Nearly a quarter of their Fellows lived outside England; the address of 35 was in India, of 34 in Africa, of 32 in foreign countries, of 13 in Australia and New Zealand, but only of two in Canada. Was it any wonder that the Society was sending a mission to the Dominion on the occasion of the Pan-Meteorological Conference which the Royal Society of Canada had convened! They hoped to see, as a result of this Conference, a closer union between the working meteorologists of the Empire. They had worked long for it in this country, and now that the Dominion of Canada had taken the first step in calling the Conference, and the Commonwealth of Australia had

responded by sending the chief of their newly created Federal Meteorological Service, it only remained for India, Africa, and the Isles of the Sea to fall into line. The Sea itself, thanks to the Navy, was there already.

OLD ENGLISH MELODY.—"Blow high, blow low."

Mr. BALDWIN LATHAM said that he had very great pleasure in proposing the toast of "Kindred Institutions." Although reminded by the President of the somewhat isolated position of the Society, they were doing good work which was useful to other institutions. Many institutions depended largely upon meteorology; he might refer to the Geological Survey and Geological Society, and, if he might be permitted, he would like to urge upon the Geological Survey to take a leaf out of the book of the United States Geological Survey, who not only studied the geology of the country, but also gauged the rainfall, published records of rainfall, the flow of water off the ground, floods, low water, etc., which were always ready to hand in carrying out water works investigations, and were of immense value. They did not trespass upon the borders of the Scottish Meteorological Society, but worked with them with a good will. The Meteorological Office was the only department issuing forecasts in advance, and these were only for a limited period. The Institution of Civil Engineers had many members who took a great interest in meteorology, and some of the past Presidents of the Institution had also been prominent Fellows of the Society. The Institution, as a body, gave the Society encouragement by placing their splendid meeting-room at the disposal of the Society. The Ordnance Survey was a body upon which they relied for the making of their maps; they had kept meteorological and other records in the past, though they did not seem to do so at present. The Royal Geographical Society were doing good service in exploration. The Aeronautical Society aided them in the study of the upper air. Last, but not least, he would mention the British Rainfall Organization, most valuable for its study of the fluctuations of the water-supply. It was started by the late Mr. G. J. Symons, who might well be considered its patron saint, and it was being continued by the occupant of the Presidential chair, Dr. H. R. Mill, and could not be in better hands. With the toast he would couple the names of Dr. J. J. H. Teall, F.R.S., Capt. H. G. Lyons, F.R.S., and Mr. Andrew Watt.

Dr. J. J. H. TEALL said that he regarded it as a great honour to be the first to reply to the toast, especially as some other Institutions might seem to have a prior claim to this distinction. If he might be permitted to refer to Mr. Baldwin Latham's critical remarks about the Geological Survey, he could only say that he entirely sympathised with those remarks. It always seemed to him that the bearing of the work of the Geological Survey in economic matters was particularly in two directions, *i.e.* that of coal-mining, and that of water-supply and sanitation. He was well aware that their work in the latter direction would not bear comparison with that of the Institution referred to, but he would like to mention that during the past few years they had done something. The Geological Survey had published a series of memoirs on the underground water-supply of Counties, and had been fortunate in securing the services of Dr. Mill to prepare a series of rainfall maps for incorporation in those memoirs. He would also point out that a Committee of the Royal Geographical Society, of which his colleague, Dr. Strahan, was a member, were making a study of certain river basins from the point of view which Mr. Latham had referred to. The Geological Survey and Geological Society were classed as kindred Institutions, and if time permitted, it would not be difficult to prove the legitimacy of their claim to that position. Dr. Williams had said that in a certain sense geology was a monument to meteorology; and this was undoubtedly true, for many rocks gave evidence of the meteorological condi-

tions under which they were formed. It is now known, for example, that arid climates have prevailed more than once in Northern Europe, and that glacial conditions have occurred at different periods of the world's history and in different places. He referred also to the work of Mr. Harmer on the influence of the winds upon climate during the Pleistocene epoch, and concluded by expressing the hope that some day or other weather charts of the world would be issued under the auspices of the Royal Meteorological Society.

Captain H. G. LYONS said that he supposed he had been selected to reply to the toast of "Kindred Institutions" because he was conversant with an area outside the British Isles. His knowledge was not world-wide, but only extended to the land of Egypt, the Sudan and the Nile. Mr. Baldwin Latham had referred to the question of rainfall and river variations, but in Egypt they had next to none of the one, and only one of the other. In a small country like Egypt some concentration of work was necessary, and the Survey Department had to collect observations relating to more than one science; thus the meteorological and geological work fell to the lot of one Department. The opening up of the Sudan was of recent date, but they were gradually establishing a network of stations from which they hoped to receive valuable results, for the rise and fall of the Nile entirely depended upon the rainfall of the Abyssinian mountains, and this was a part of the great monsoon system of the Indian Ocean. But though observations were essential, their discussion and study must not be allowed to fall into arrears; when the Survey Department took over the control of the Abassia Observatory, he had found a pile of documents, and on making enquiry concerning them, found they were the result of daily observations taken at 2.30 p.m., which were made in answer to an enquiry received some fifteen years previously. The name and address of the person making the enquiry had been lost, but the observations had been allowed to go on accumulating; they had now been compiled, and so were not entirely useless. He could fully sympathise with Dr. Mill on the problem of meteorological observations to which he had referred. The climatic conditions of north-east Africa were less complex than in many parts of the British Empire, and the solution of the various problems should prove a less difficult task. The climate of Egypt was not always as arid as it is to-day. There were opportunities for meteorological observations everywhere, and simple observations, if made carefully and conscientiously, would always be of value.

Mr. ANDREW WATT, in responding to the toast of "Kindred Institutions," said that it was a great honour to reply in such a goodly company for the Scottish Meteorological Society. It was indeed a very significant courtesy that the name of the Scottish Society should appear on the Toast List. Beyond all other sciences that of Meteorology should be independent of international boundaries, and it was fortunate for the happy relations between Scotland and England that the Royal Meteorological Society had for at least one term of office a Scot in its Presidential chair. As regards the distinguished Director of the Meteorological Office, he might recall a story of a Scot who was somewhat boastfully upholding the literary fame of his country. "There's Robbie Burns," he said, "a Scotsman; Sir Walter Scott, a Scotsman; Thomas Carlyle, a Scotsman. They're all Scotsmen." "Yes," said an Englishman, "but what about Shakespeare?" "Well," was the reply, "I'm not just prepared to aver that Shakespeare was a Scotsman; but this I will say, that his abilities would justify the inference." And so of Dr. Shaw, if he was not a Scot, he might have been.

PART SONG.—"Our Ship now goes with the Pleasant Gale."

Mr. F. CAMPBELL BAYARD in a few words proposed a vote of thanks to the Chairman, remarking that they all knew what Dr. Mill had done for the Society. At a great sacrifice of time he had decided to represent the Society at

the Meteorological Conference in Canada. They all wished him a pleasant voyage.

THE PRESIDENT, in expressing his thanks, referred to the novel arrangement of the tables, and hoped that by arranging the party in little groups of four the social opportunities of the evening had been turned to the best account.

QUARTET.—"Lovely Night."

The proceedings then terminated.

The Music was under the direction of Mr. H. Schartau.

PROCEEDINGS AT MEETINGS OF THE SOCIETY.

May 20, 1908.

Ordinary Meeting.

Dr. HUGH ROBERT MILL, President, in the Chair.

ROBERT VAUGHAN GOWER, Ferndale Lodge, Tunbridge Wells;
DAVID HANSON, Salterlee, Halifax;
WILLIAM FRANCIS KEATES, Cannelton, Indiana, U.S.A.;
ALBERT LANCELOT LANG, 3 Avenue Road, Isleworth, W.;
WILFRID RAVENSHAWE FELLOWES LUKIS, Yokohama, Japan;
SAMUEL JAMES AUGUSTUS MILLS, Preston Road, Blackburn;
BASIL RONALDS, Swainshill, Hereford; and
Capt. HUGH WILLIAMS, Ismailia, Egypt,
were balloted for and elected Fellows of the Society.

THE PRESIDENT said that before commencing the regular business, he would like to remind the Fellows present that the Annual Dinner of the Society would take place at the Trocadero Restaurant on Tuesday, June 16. He wished to impress upon them the importance of being present and also bringing their friends. The Society was inviting a certain number of distinguished guests, and one of them, Lord Strathcona, the High Commissioner for Canada, had already accepted the invitation. The President stated that the Society was taking part in a Conference of Meteorologists of the British Empire called by the Royal Society of Canada to meet in Quebec in July. This was, he believed, the first occasion in which one of the Colonies had taken the initiative in bringing together a scientific Conference. The Dinner would take place before the next meeting of the Society, and he trusted that country members arriving for one function would remain for the other.

The following communications were read:—

1. "UPPER AIR OBSERVATIONS IN EGYPT." By B. F. E. KEELING, M.A. (p. 259).

2. "BALLOON EXPERIMENTS IN BARBADOS, NOVEMBER 6-8, 1907." By Professor J. P. D'ALBUQUERQUE, M.A. (p. 265).

3. "OBSERVATIONS ON THE COLOUR OF LIGHTNING, MADE AT EPSOM, 1903-1907." By SPENCER C. RUSSELL, F.R.Met.Soc. (p. 271).

June 17, 1908.

Ordinary Meeting.

Dr. HUGH ROBERT MILL, President, in the Chair.

ARTHUR CAPEL VALENTINE BAINES, Somerset East, Cape Colony;

JAMES NICOLL HOOD, Woodside, Muirfield Road, Inverness;
BERTRAM FRANCIS EARDLEY KEELING, M.A., Helwân, Egypt;
VINCENT CLAUDE LARGE, 5 Ashbourne Road, Fulwood Park, Liverpool;
Hon. CHARLES STEWART ROLLS, M.A., South Lodge, Rutland Gate, S.W.; and
Capt. THOMAS SHAILER WESTON, 18 Clarendon Road, Holland Park, W.;
were balloted for and elected Fellows of the Society.

The following communications were read:—

1. "AN ELEMENTARY EXPLANATION OF CORRELATION: ILLUSTRATED BY RAINFALL AND DEPTH OF WATER IN A WELL." By R. H. HOOKER, M.A., F.R.Met.Soc. (p. 277).

2. "THE HONG-KONG TYPHOON, SEPTEMBER 18, 1906." By LAWRENCE GIBBS, Assoc.M.Inst.C.E. (p. 293).

CORRESPONDENCE AND NOTES.

The Franco-British Exhibition and Meteorology.

The Executive Committee of the Franco-British Exhibition, when arranging for the Exhibition at Shepherd's Bush, decided to organise a British Science Section, which should deal with all forms of scientific research, and should include historical apparatus, which has aided in the advancement of scientific knowledge. A building containing 14,000 square feet of floor space was erected for the purpose, and a Science Committee appointed for carrying out the scheme. Subsequently, for the purposes of organisation, fifteen sub-committees were formed. That for Meteorology consisted of Mr. W. W. Bryant, Major Baden-Powell, Mr. E. S. Bruce, Capt. E. W. Creak, F.R.S., Dr. C. Chree, F.R.S., Mr. R. H. Curtis, Capt. C. Hepworth, Mr. R. G. K. Lempfert, Dr. W. J. S. Lockyer, Mr. W. Marriott, Dr. H. R. Mill, Mr. W. E. Plummer, Dr. A. A. Rambaut, F.R.S., Dr. W. N. Shaw, F.R.S., and Mr. C. T. R. Wilson, F.R.S. Dr. Shaw was the convener.

A large and interesting collection of valuable instruments, apparatus, maps, charts, diagrams, photographs, books, models, etc. has been got together, and this forms an important section in the Science building.

The Exhibits are arranged under the following sections:

A. Collection and discussion of observations from Warships and the Mercantile Marine.
B. Observatories.
C. Climatology.
D. Rainfall and Hydrometrical Statistics.
E. Telegraph Reporting.
F. Experimental Investigations.
G. Illustrations of Meteorological Work of Special Character.
H. History and Literature of Meteorology.
I. Atmospheric Electricity.

The principal exhibits have been lent by the Meteorological Office, the Royal Meteorological Society, the National Physical Laboratory, the Royal Observatory, Greenwich, the Radcliffe Observatory, Oxford, and Dr. H. R. Mill. Other exhibits have been contributed by Mr. J. Aitken, F.R.S., Mr. E. S. Bruce, Mr. A. W. Clayden, Messrs. J. W. Gray and Sons, Dr. W. J. S. Lockyer, Mr. W. Marriott, Mr. W. E. Plummer, Mr. J. Tennant, and Capt. D. Wilson-Barker.

It was intended that a working Climatological Station with instruments in position should be equipped by the Royal Meteorological Society in the grounds of the Exhibition, and that observations should be made daily at 9 a.m. and 9 p.m. Unfortunately, the Exhibition authorities did not provide a site suitable for the exposure of the instruments, so the station could not be arranged.

RECENT PUBLICATIONS.

Barometric Gradient and Wind Force. Report to the Director of the Meteorological Office on the Calculation of Wind Velocity from Pressure Distribution, and on the Variation of Meteorological Elements with Altitude. By ERNEST GOLD, M.A. Published by the Authority of the Meteorological Committee. London, 1908. 4to. 44 pp. and 15 pl. Official Copy, M.O. No. 190.

This paper is divided into two sections. The first deals with the calculation of wind velocities from the distribution of the isobars according to the theory of Ferrel, and Guldberg and Mohn. The second contains an account of the results obtained from kite and balloon ascents in Germany and in England during 1905 and 1906, and a comparison between the values obtained for the wind velocity and direction at 1000 metres altitude by experiment and according to calculation.

Dr. Shaw, in the preface to this Report, points out that the relation of wind force to barometric gradient is a fundamental question in modern meteorology.

Maryland Weather Service. Volume II. Baltimore, 1907. 8vo. 515 pp.

This is the second of a series of *Reports* dealing with the climatic features of Maryland. The first volume issued by this Service was general in character, and presented all that was then known regarding the physiography and meteorology of the State. The present volume contains a very exhaustive "Report on the Climate and Weather of Baltimore and Vicinity," and represents the results of many years' study of the Baltimore region. It is doubtful if the weather of any district has been so thoroughly studied as this region has been by Dr. Fassig.

The Report is divided into two parts. The first deals with the average and extreme values of the meteorological elements recorded in the city of Baltimore. The discussion is based upon observations extending over a period of nearly a century. The second part deals with types of weather experienced in Baltimore and the vicinity. The Report is profusely illustrated, being accompanied by 24 plates and 173 illustrations, many of which are in colours.

A summary of the principal climatological results for the years 1871-1904 are given in the following table:—

MONTHLY RESULTS OF CLIMATOLOGICAL OBSERVATIONS, BALTIMORE, 1871-1904.

MONTHS.	Pressure.	Temperature.						Relative Humidity.	Amount of Cloud.	Rain.	
		Means.				Extremes.				Amount.	No. of Days.
		Min.	Max.	Range	Mean.	Min.	Max.				
	ins.	°	°	°	°	°	°	%		ins.	
January	29·995	27·4	40·6	13·2	34·0	−6	73	69·5	5·9	3·20	12
February	29·968	28·5	42·4	13·9	35·5	−7	78	66·5	5·0	3·70	11
March	29·889	34·4	49·6	15·2	42·0	5	82	64·9	5·3	3·99	13
April	29·877	44·8	61·6	16·8	53·2	24	94	60·1	5·7	3·27	11
May	29·852	55·6	72·9	17·3	64·3	34	96	63·6	5·8	3·63	12
June	29·851	64·5	81·8	17·3	73·1	47	99	66·6	5·1	3·78	10
July	29·850	69·4	85·8	16·4	77·6	55	104	66·4	4·9	4·66	12
August	29·869	67·3	83·3	16·0	75·3	51	100	69·2	4·6	4·20	11
September	29·946	60·4	76·5	16·1	68·4	39	101	70·4	4·3	3·85	9
October	29·942	49·2	65·6	16.4	57·4	30	90	67·6	5·0	2·99	9
November	29·976	38·7	53·1	14·4	45·9	15	79	65·8	4·9	2·99	10
December	29·988	30·3	43·8	13·5	37·1	−3	73	67·2	5·0	3·07	11
Year	29·917	47·5	63·1	15·6	55·3	−7	104	66·5	5·1	43·33	131

National Antarctic Expedition, 1901-1904. *Meteorology, Part I. Observations at Winter Quarters and on Sledge Journeys, with Discussions by Various Authors.* Prepared under the Superintendence of the Director of the Meteorological Office with the Co-operation of a Committee of the Royal Society. Published by the Royal Society, 1908. 4to. London. (14 + 548 pp., 15 plates, and 5 charts.)

The meteorological work of this Expedition was under the charge of Lieutenant C. Royds, who gave a very interesting account of the work done, and the difficulties which had to be contended with, at the Meeting of the Royal Meteorological Society in November 1904. (*Quarterly Journal*, 31, 1905, p. 1.)

This volume contains the meteorological Journal of the *Discovery*, giving two-hourly observations from February 9, 1902, to February 15, 1904, and in addition the meteorological observations made at Erebus Island Camp, lat. 77° 51′ S., long. 166° 45′ W., and on the various sledge journeys from winter quarters, are printed *in extenso*. These observations extend over 246 pages. Summary tables of the *Discovery* Expedition, and of the German, Swedish, and Scottish National Expeditions, are also given, together with those of the relief ship *Morning*. The results have been discussed in the following papers, which are printed in the volume:—"Climatology of South Victoria Land, and the Neighbouring Seas," by M. W. Campbell Hepworth; "Notes on the Observations of Temperature of the Winter Quarters of the *Discovery*," by Dr. Charles Chree; "Notes on Open-air Temperature, Stream Temperature, and on Terrestrial Radiation," by W. H. Dines; "Notes on the Readings of the Aspiration Psychrometer and of the Dry and Wet-bulb Thermometers, and on the Observations of Evaporation and Precipitation, and of the Evaporation of Ice," by W. H. Dines; "Notes on the Observations of Barometric Pressure," by R. H. Curtis; "Discussion of the Observations of the Direction and Force of Wind at Winter Quarters and on the Sledge Journeys," by R. H. Curtis; "Notes on the Records of Sunshine and the Observations of Clouds," by R. H. Curtis; and "Discussion of the Observations of Atmospheric Electricity," by C. T. R. Wilson. Lieutenant Royds contributes some notes on the meteorological instruments and their exposure; and Dr. E. A. Wilson a series of beautiful plates illustrating solar and cloud phenomena. Dr. Shaw, in the preface, sums up what appear to be the salient features of the climate, according to the two years' experiences of the explorers, as follows:—

"Although the winter quarters were regarded as an exceptionally warm position in relation to others in the locality, temperature ranged from a maximum of only 42° F. to a minimum of −58°·3 F. Fluctuations are extraordinarily rapid and violent at all seasons; they are sometimes, but not always, associated with changes of wind direction. Polar winds often bring with them an increase of temperature.

"The daily range is large in consequence of the sudden fluctuations, but the mean diurnal variation, as represented by the average of the two-hourly readings, amounts to only 3° in midsummer and 1° in midwinter. The time of maximum, as regards the latter, is rather dubious, but there is evidence of a diurnal and semidiurnal oscillation of temperature even in the Antarctic night.

"The summers were remarkably cold. Very few days gave a mean temperature above the freezing-point. The highest mean temperature for any month was 26°·2 F., the lowest −21°·0 F. The air is remarkably dry and transparent, fog is comparatively infrequent; precipitation is slight, but there may be deep drifts of snow. Sunshine is remarkably abundant; the total for 1903 equalled that for Scilly, and in December of that year an average of 16 hours per day was registered. The sun's rays are intensely hot, and terrestrial radiation extremely vigorous.

"Pressure ranged between 30·181 and 28·140 ins., the two extremes occur-

ring in consecutive months of 1902. The barometer stands high as compared with the values obtained for other positions in the Antarctic. The sequence of pressure changes as shown on the barographic records presents no very noteworthy peculiarities, and the use of the barometer for anticipating coming weather is less effective than in this country.

"The pressure observations show the common semidiurnal oscillation. It amounts to 0·002 in., with maxima at about 10 a.m. and 10 p.m. at all seasons of the year. The variation of 24 hours' period has, on the average, an amplitude of twice that amount, but the times of maximum are different at different seasons.

"The changes of pressure in high southern latitudes may be regarded as associated with the passage of cyclonic depressions much in the same way, *mutatis mutandis*, as elsewhere.

"The surface winds are chiefly Easterly. Northerly and Southerly winds occur, but winds from between the South-west and North-west are almost unknown. The chief characteristic of the wind is its gustiness. Gales are experienced from every quarter between North-east round to South-west on the Eastern side, but, on the whole, they are not so frequent as in the British Isles.

"The direction and motion of the lower clouds may be from any point of the compass. The resultant is a moderate frequency from the South-east; there is a marked deficiency as regards the West.

"The resultant motion of smoke from Mount Erebus is from the South and West, and that of the upper clouds from the West.

"Subject to some uncertainty on the state of the instrument, the mean electric force potential is rather lower than at Kew, but abnormally high in drifting snow or ice crystals. A diurnal variation is shown in summer with a maximum in the middle of the day, and a minimum in the early morning hours. The seasonal variation has a maximum in summer and a minimum in winter.

"No relation is shown between potential and aurora."

The observations and results given in this volume are a most valuable addition to our knowledge of the conditions of the Antarctic regions.

There still remain for publication the discussions of the special features of the traces from the recording instruments, obtained at the winter quarters, and of about one thousand synchronous charts of the regions south of 30° S. lat. which have already been prepared from the daily observations at Greenwich noon contributed by international co-operation.

METEOROLOGICAL LITERATURE.

The following titles of papers bearing on Meteorology have been selected from the contents of some of the periodicals and serials which have been received in the Library of the Royal Meteorological Society. This is not a complete list of all the published meteorological articles, but only shows those that appear to be of more general interest.

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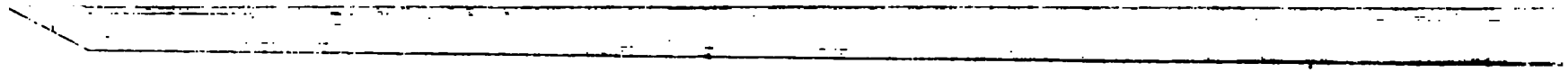

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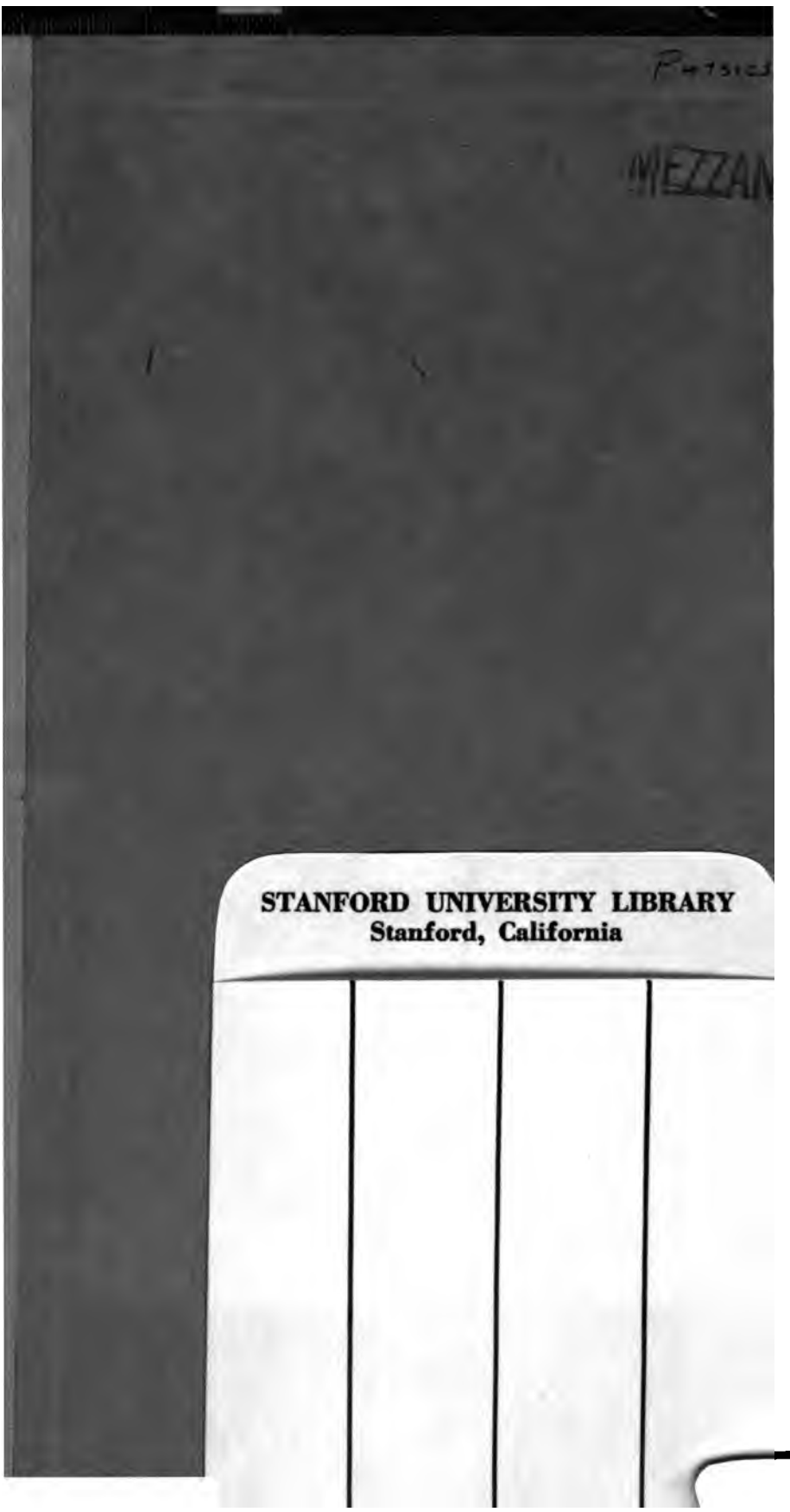
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